BOLT BERANEK AND NEWMAN INC

CONSULTING • DEVELOPMENT • RESEARCH

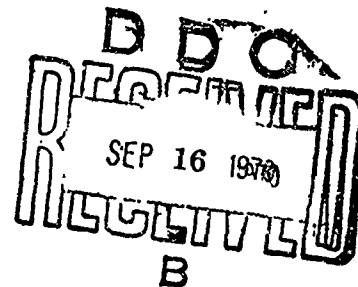AD711378

INFORMATION PROCESSING MODELS AND

COMPUTER AIDS FOR HUMAN PERFORMANCE

SEMIANNUAL TECHNICAL REPORT NO. 7

31 July 1970

D D C

SEP 16 1970

RECEIVED

B

Prepared for:

Air Force Office of Scientific Research
1400 Wilson Boulevard
Arlington, Virginia 22209

CAMBRIDGE   NEW YORK   CHICAGO   LOS ANGELES

DISCLAIMER NOTICE

THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

INFORMATION PROCESSING MODELS AND
COMPUTER AIDS FOR HUMAN PERFORMANCE

SEMIANNUAL TECHNICAL REPORT NO. 7
31 July 1970

Prepared for

Air Force Office of Scientific Research
1400 Wilson Boulevard
Arlington, Virginia   22209

TABLE OF CONTENTS

Report No. 2008   Bolt Beranek and Newman Inc.

SEMIANNUAL TECHNICAL REPORT NO. 7

Period 1 January - 31 July 1970

Title: Information Processing Models and
        Computer Aids for Human Performance

TASK 1:   SECOND-LANGUAGE LEARNING

1.   Technical Problem

The task is to develop a computer-based system to aid students in
acquiring the phonology of a second language, and to ascertain
the efficacy of the approach through a controlled experiment.

2.   General Methodology

Laboratory experiments.

3.   Technical Results

An experiment to test the effectiveness of the system relative to
an appropriate control treatment was designed. It involves dis-
plays for vowel pronunciation at the outset, and the plan is to
add displays for reduced vowels and initial consonant aspiration
as the study progresses. After completion of system modifications,
and of validation studies for the specific stimuli used, a pre-
liminary experiment was begun. This was terminated due to a pre-
viously unrecognized ability of our speakers to mimic correct
English pronunciation, given minimal time delay, whereas their
normal speech was highly accented. A new experiment incorporating
modifications to meet this and other problems is currently in
progress.

4.   Department of Defense Implications

Language schools of the Department of Defense give instruction in
approximately 65 languages to over 200,000 students each year. The
systems under development are designed to facilitate this instruc-
tional process.

TASK 2: MODELS OF HUMAN-COMPUTER INTERACTIONS

1. Technical Problem

The purpose of this research program is to develop models
for certain types of human-computer interactions in a
time-sharing environment at the human-computer interface
level.

2. General Methodology

Laboratory experiments.

3. Technical Results

Experiments were conducted to explore methods of motivating
time-sharing system users to adopt behavior patterns that
improve overall system performance. It was found that it
is possible for a time-sharing system to provide incentives
to users that will affect their choices between alternative
methods of accomplishing a task. However, the extent of
this effect is not precisely predictable.

4. Department of Defense Implications

To design and operate computer-assisted Command and Control
systems (such as Air Traffic Control, for example) or
software development systems, it is necessary that the computer
system designer be able to predict how users will behave
with a system having given response characteristics. Also,
it is necessary to predict the relative acceptability of a
system with a given set of characteristics.

TASK 3:   PROGRAMMING LANGUAGES AS A TOOL FOR COGNITIVE RESEARCH

1.   Technical Problem

This task is an investigation of means of studying, diagnosing,
and remedying the difficulties people have in solving formal
problems.

2.   General Methodology

The method of investigation is a teaching experiment of the
following kind.   Trainee-subjects are taught the use of an appro-
priate programming language as a tool for formal problem-
solving.   Their specific difficulties in learning and applying
the language -- which is called LOGO -- are observed, studied,
and evaluated.

3.   Technical Results

Through study and analysis of data from previous teaching, we
identified several linguistic and conceptual difficulties in the
way of acquiring the skills of problem-solving.   We conceived
and designed a wireless computer-controlled vehicle to assist
students in conceptualizing formal problem-solving tasks in a
concrete context.   A prototype vehicle, complete except for
the incorporation of sensing functions, has been constructed.

We taught a LOGO-based course in introductory problem-solving
to a group of students with well-established difficulties in
formal academic work.   We carried out an experiment to evalu-
ate the validity of standard test measurements of achievement
level.

4. Department of Defense Implications

One area of direct application is to teaching basic academic
subjects and skills in military dependent schools. Know-
ledge and skill in the methods of formal reasoning and
problem-solving are important, not only in direct application
to formal work in mathematics and military science, but also
in less formal areas of problem-solving such as are encountered
in military operational planning and decision-making. Thus,
the teaching approach we are investigating could have a prac-
tical payoff in several military training programs.

5. Implications for Further Research

We expect the use of programming languages such as LOGO will
make important contributions to both the theory and practice
of education. Possible directions for further work are:
(1) the use of programming languages as the operational
framework for experimental studies on cognitive development
in children, and (2) the development of programming as a
core subject for a new mathematics curriculum. The use of
LOGO to control a robot such as the vehicle we are building,
will enhance this contribution. Further, the program-controlled
robot may provide a new framework for studying interactive
man-machine systems. With appropriate sensors and effectors,
such systems may provide useful operational applications.

TASK 4:   STUDIES OF HUMAN MEMORY AND LANGUAGE PROCESSING

1. Technical Problem

The aim of this project is to determine how people store and re-
trieve factual (non-numerical) information and how they utilize
this stored information in comprehending English text. Two of
the studies completed so far have investigated how people
retrieve factual information, and a third has evaluated two
possible strategies for interpreting text.

2. General Methodology

Laboratory experiments.

3. Technical Results

The results have indicated that people use both deductive in-
ference and inference by analogy in answering questions. The
initial search for relevant facts is apparently a parallel pro-
cess, while the checking of possible answers is a serial process.
The human strategy in sentence comprehension has been found to
proceed by combining interpretations of smaller segments into
larger segments; i.e., what is called a bottom-up processing
strategy.

4. Department of Defense Implications

Military operations in the future will utilize computer-based,
question-answering systems that can store and retrieve factual

information and that can interact with users in English. Knowl-
edge gained from these experiments is being used in a computer
project aimed toward developing such systems.

5. <u>Reports Annotated Within</u>

Collins, A.M. and Quillian, M.R. *Tripping down the garden path.*

1. PREFACE

John A. Swets

Of the tasks included in this contract, the one on second-language learning is in its fourth year, and the other three are now at the end of their first year. Six months remain under the present contract.

Our research on language learning has progressed to the stage of testing the effectiveness of a system that we have developed for instruction in pronunciation. An experiment underway compares results obtained from training using this computer-based system with results obtained using procedures typical of language laboratories. Under our system the student's utterances are automatically analyzed and evaluated, so that he does not have to depend largely or solely on his ear to determine the differences between his pronunciation and a standard, or acceptable, form. The system includes a CRT display that shows the amount of any discrepancy, and the kind of vocal adjustment the student must make in order to correct it.

Most of our effort to date has been devoted to a display of inferred tongue-body position during vowel sounds. Displays for reduced vowels and for aspiration during initial consonants will be included in the present test. These three displays are directed at the major problems confronting the native speaker of Spanish as he attempts to learn English. Other significant aspects of speech susceptible to automatic analysis include vowel length, voicing during fricatives, and stress. If we are able to evaluate the system further, in the context of one of

the centers of the Defense Language Institute, we plan to add a
pitch extractor so that the system can be applied to tonal lan-
guages.

Our efforts to develop models for man-computer interactions have
focused this period on experiments. The experiments manipulated
the computer's response characteristics in an attempt to influence
the user's choice of commands. Certain incentives provided by a
time-sharing system affected the user's choice among alternative
methods of accomplishing his goal, with a resulting improvement
in the efficiency of the total (computer-plus-user) system. The
objective of this task is to develop information for the computer-
system designer, information about the interaction of computer
and human response characteristics, and about the relative accept-
ability of various sets of computer characteristics.

We continue, under our third task, to investigate how the diffi-
culties people face in solving formal problems can be studied,
diagnosed, and remedied. During this period we moved from an em-
phasis on conceptual barriers to an emphasis on some psychological
barriers, including issues of motivation, relevance, and attitudes
about learning. An experiment was conducted in which the computer-
programming language LOGO was taught to students who had a history
of resisting formal academic work. The side effect of the teach-
ing on the students' reading skills was also assessed. We have
now constructed, complete except for sensing functions, the wire-
less, computer-controlled vehicle that will give a concrete context
to formal problems.

Our fourth task is to determine how people store and retrieve
factual information and how they use this stored information in

2

comprehending English text. The results are being applied
(under a separate contract) to the design of a computer-based
question-answering system that interacts with users in English.
Two experiments during the past period examined how people re-
vise a mistaken interpretation of a part of a sentence. The
indications are that reprocessing involves only the words mis-
interpreted, and that the human strategy in sentence comprehen-
sion is one of combining smaller into larger segments—a so-called
bottom-up processing strategy. Under a top-down strategy, as
used in computational linguistics, the individual would return
to a point before the mistake and reprocess the remainder of the
sentence.

APPENDICES (Continued)

2. SECOND-LANGUAGE LEARNING

Daniel N. Kalikow and Dennis H. Klatt

2.1 INTRODUCTION

The aim of this work is to develop and test a computer-based sys-
tem to aid students in acquiring the phonology of a second language.
The system was built to test the hypothesis that real-time acoustic
analysis of a student's speech and the provision of appropriate
visual feedback based on such an analysis can be effective in
teaching the phonology of a new language.

During the previous six-month reporting period, the transfer to
the smaller PDP-8/L computer was completed. All apparatus was
transferred to its present location, hardware interfaces were in-
stalled, and, at length, system debugging and calibration proceeded.
Preliminary implementation of a tongue-position display was begun.

At the outset of the present reporting period, the tongue-position
display for improving vowel pronunciation of Spanish-speaking
subjects (Ss) was operational in the configuration described in
the previous report. Since that time, preliminary system development
has been completed and a full-scale experimental evaluation
has been undertaken. The present report describes the activities
leading to the current experiment within a framework of goals de-
rived from a consideration of the design of that experiment. The
following phases of activity were required before evaluation could
commence.

A. Experimental design

B. Human-engineering of the system so that naive Ss could
    use it proficiently

C. Modification of the system to conform to requirements
    of the experimental design

D. Pilot work to assure the phonological validity of
    the display

The following material is in rough chronological order. Concurrent
activities along more than one of the above fronts are described
in their appropriate logical sequence.

2.2 EXPERIMENTAL DESIGN

During the course of our work on a computer-aided system for teach-
ing the phonology of a second language, we have gradually spec-
ified the parameters of the particular learning situation in which
the first version of the system would be developed and tested. We
chose a particular pair of languages—Spanish and English—as
source and target. We analyzed the acoustic properties of the most
common errors made by Spanish speakers producing English words, and
we chose the most salient ones for subsequent work.* This restricted
field of activity was necessitated by the complexities of speech
and the limitations of time. We felt that it would be possible to

---

*It should be remembered that there is no theoretical reason im-
peding the addition of other language pairs and speech-parameter
displays to a general phonology instructional system. Of course,
each new aspect would necessitate a thorough acoustical analysis
along the lines presented in our previous reports.

execute and analyze an experiment in second-language learning
within the remaining time on the project if we restricted our
attention to one primary and two secondary parameters of speech
production in Spanish-speaking people. (1): vowel pronunciation
in monosyllabic words. This parameter had been worked with most
extensively in previous development, and the relevant display,
tongue position during the vowel portion of the utterance, had
been well developed. (2); reduced vowel pronunciation in poly-
syllabic words. Spanish speakers have difficulty with the schwa
vowel, and the strategy for this display involves detecting the
syllable where the schwa should occur, and displaying tongue
position during this portion of the utterance along with some
indication of the correct position. (3): aspiration of initial
stops in monosyllabic words. Spanish speakers have difficulty
in producing enough aspiration before onset of voicing. This
display involves measurement of aspiration intensity and time of
voicing onset, indicating desirable values for each parameter for
the student to compare with his own efforts.

At the time when the experimental design was taking shape, the
latter two displays were still conceptual, no software work having
been done on either of them. This was because so much effort was
going into the vowel display, the most difficult of the algorithms.
The reduced-vowel display must be built upon a finished vowel dis-
play, so it had to wait; and the aspiration display was quite
straightforward, so its initiation could be deferred. We felt
that we should devote our efforts toward the design and execution
of a large experiment on the system's effectiveness, with the first
weeks of training being given solely to the vowel display. We
realized that considerable modifications from a research-oriented
system would be necessary before naive Ss could use it; and so

8

we determined to make those changes and the others that logic and
experimental design would require, and then get on with the exper-
iment as soon as possible. We would of course keep in mind the
subsequent changes that the latter displays would require, and
would plan for their inclusion in the ongoing experiment.

2.2.1 Basic Considerations

The experiment must produce answers to two interrelated questions.
(1) Is the system effective as an aid to phonology instruction?
(2) How does it compare with the results obtainable through ex-
tant techniques? Question (1) is of course obvious; the efficacy
of the system must be demonstrated if we are to take it seriously.
Question (2) is far more subtle, however, since it revolves about
the crucial issue of the appropriate control group(s).

Consider the nature of the system in its configuration for vowel
instruction (see Figs. 2.1 and 2.2). The capabilities of the ap-
paratus at the outset of the reporting period were these:

> 1. S executes a section designed to normalize the operation
> of the system to his own voice characteristics: he speaks
> five Spanish words, and the acoustic properties of those
> words are used in all subsequent feedback computations.
> This will be discussed at greater length below. It is not
> really a capability, but is rather a requirement inserted
> here for completeness of description.

> 2. S selects a Language Master (LM) card containing a re-
> cording of a teacher's voice speaking a monosyllabic English
> word containing one of 12 English vowels. He enters it into
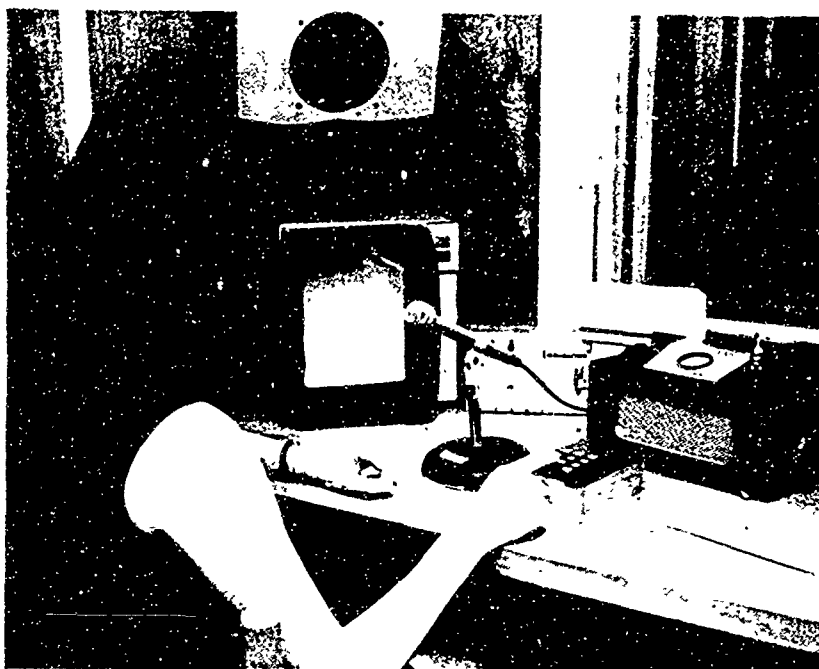
Fig. 2.1 Subject room configuration. Apparatus, from left to
   right: loudspeaker, CRT, microphone, VU meter, button-box,
   Language Master with card, and, on table, stack of cards.

Fig. 2.2 Control room configuration. Apparatus, from left to
   right and top to bottom: history tape recorder, monitor loudspeaker,
   power amplifier, tape loop recorder, preamplifiers, filter bank,
   teletype, monitor microphone, slave CRT, A/D converter, PDP-8/L
   computer.

the Language Master card reader and hears it through his
loudspeaker as it is recorded on the tape loop. He is then
ready to begin work on improving his pronunciation of that
word.

3. S instructs the machine to begin by pressing the STORE
button on his response panel. First, he hears the recording
of the teacher's voice speaking the English word. He then
receives a visual cue to repeat it. He does so, recording
it on the tape loop. The computer detects the beginning and
end of the vowel portion of the word, and stores an inferred
tongue position each 10 msec. Following completion of the
utterance, S is immediately shown a display containing the
tongue trace and a small rectangular target indicating the
desirable region for the vowel in question. Since he knows
that the larger rectangle within which the above information
appears is a schematic representation of the left cross-
section of the mouth, he receives instruction on how to move
his tongue, the crucial articulator, to the desired location.

4. S may listen to the contents of the tape loop at any time,
without changing the contents of the CRT display. Pressing
the RECALL button on the box of buttons before him produces
playback of the teacher's voice and of his own last recording
made with the STORE button. Ss are encouraged to listen to
the recordings, to pick out differences between the vowels,
to evaluate their own attempts, and to make sure that they are
paying proper attention to the non-vowel aspects of each of
the words.

5. If S wishes to receive immediate tongue position feedback
for a series of trial utterances without the necessity of

11

using the STORE procedure for each, he may issue a command
providing for continuous feedback. Here, the microphone is
left on, and the CRT displays the target within the larger
rectangle. Any vowel sound over a criterion loudness level
produces virtually immediate feedback on the CRT in the form
of a trace of inferred tongue-position points. Thus S may
attempt different versions of the whole word or of the vowel
portion, and can try to change his utterance such that the
feedback reaches the target.

6. There are 12 different vowels which S works with during
the course of his training. For each one, he is free to use
the STORE, RECALL, and continuous-feedback buttons in any
sequence. He therefore has the capability to mimic a tea-
cher's voice, listen to his attempts, and to receive spec-
ialized instruction about his vowel pronunciation.

Let us now return to a consideration of the appropriate control
group(s), given the above brief exposition of the activities of
the experimental Ss. First: what is the state of the art in
phonology instruction?

2.2.2 Extant Procedures

Phonology is a difficult skill to teach. The main source of the
difficulty stems from the fact that learning a second language
requires auditory and kinesthetic discriminations which are irrel-
evant to the overlearned behavioral repertoire of the student's
first language. If the phonology of a new language is to be learned
at all, the student must learn to make those new discriminations,
and this requires the presence of reinforcements.

Instruction in phonology is becoming increasingly important as the goals of language teaching change from mere reading knowledge to effective overall communication. To meet this growing need, two main approaches have heretofore been taken.

2.2.2.1 <u>Individual instruction</u>. This method requires a skilled teacher to aid the student, and is of limited efficiency since classes cannot be too large. The student mimics the teacher, and the latter corrects mispronunciations by appropriate verbal in-structions. Much out-of-class practice is necessary to maintain the new habits. Sometimes this is helped by drills contained in a good text; often it is supplemented by the language laboratory, discussed below.

2.2.2.2 <u>Language laboratory</u>. This technique, so costly to im-plement and introduced with so much fanfare, was expected to bring a revolution in the teaching of languages. So far, it has lost through ineffectuality what it has gained in increased efficiency of teacher utilization. The basic premise of the language labor-atory was that giving the student the opportunity to mimic a tea-cher's voice, and possibly to repeat the process, would build up proper verbal habits by pointing out to him the areas where his pronunciation disagrees with the recording of the teacher's voice. To further aid his learning, laboratories were constructed so as to allow a monitor to cut into the earphones of a given student and supplement the instructions. In reality, however, such moni-toring occurs extremely rarely and usually not at all since a given laboratory is used concurrently by students studying several dif-ferent languages; a single monitor cannot aid all students. Even if the students are all working on the same language, their number is usually so large that the quantity of monitoring for each is

13

minuscule. The student is thus dependent on his own resources
for improving his pronunciation, and the result is often simply
an improvement in vocabulary with concomitant overlearning of bad
pronunciation habits, since the student is unable to improve by
his own bootstraps.

2.2.3 Control Group

We have introduced the general capabilities of the system and have
contrasted it with procedures currently in use. With these con-
siderations in mind, let us now turn our attention to the issue
of the proper control treatment. Several potential treatments
will be presented, and all but one of them will be rejected: some
on grounds of inappropriateness, and others because of the inev-
itable scarcity of time, money, or the population of potential Ss.

2.2.3.1 Subject selection criteria. The first stage in any ex-
periment of this type, no matter how many groups are involved, is
the selection of a homogeneous sample. Therefore, all potential
Ss will be screened in some standard manner, with a specifiable
algorithm used for acceptance into the program. After this point,
Ss will be placed into subgroups by a procedure appropriate to the
intended statistical analysis. We shall henceforth assume that
all discussion of treatments concerns statistically equivalent sub-
groups. Screening procedures will be discussed below.

2.2.3.2 No-treatment control. As it developed, the local popu-
lation of Spanish-speaking people contains a large proportion of
recent immigrants to the United States. Their English pronuncia-
tion might be expected to improve over time in the absence of ad-
ditional training, as they are exposed to an English-speaking en-
vironment. A no-treatment group would control for this contingency;

14

but it was rejected because of the inherent uncertainty about the linguistic environment of immigrants in their own community, and because of the scarcity of potential Ss.

2.2.3.3 <u>Individual-instruction control</u>. To determine whether the system is more effective than individual tutorial or class instruction, a control group given that treatment would be instructive. It was rejected not only because of resource scarcity, but for two other reasons. (1) We could not specify exactly what curriculum would be followed in such instruction, and what its relevance might be to the specific skills taught in the experimental treatment. (2) The inherent inefficiency of the tutorial technique does not merit a specific control group, since the rationale of this system, and that of the standard language laboratory, is that automated group instruction in phonology will become essential in the future, as individual instruction becomes costly.

2.2.3.4 <u>Language-laboratory control: I</u>. The performance of the system might be tested by comparison with a group of Ss which, after selection, was put through a standard language-laboratory curriculum at a nearby institution. This was rejected for the same reason given in (1) under Section 2.2.3.3.

2.2.3.5 <u>No-auditory-feedback control</u>. The crucial innovation in the system is the provision of visual feedback as an aid in moving the tongue to the appropriate position in the mouth for the production of a given vowel sound. The purest test of the efficacy of this feedback would be to minimize auditory feedback to the S; perhaps eliminating the capability of listening to his recordings, and in the limit removing the teacher's recorded voice as a model and/or covering S's ears with muffs or masking noise, making him

effectively deaf. This possibility was not pursued for two rea-
sons. (1) It is irrelevant to the issue of second-language learn-
ing. The visual feedback was designed to act as a teacher in a
language-learning situation, and as such should be compared to a
control treatment containing as many of the standard features of
that situation as can practicably be included. This treatment
would require the system to be tested as if it were an aid to
pronunciation for the deaf; and since there are so many other speech
parameters in the production of even monosyllabic words, asking a
single display to carry the entire burden is an unfair test of its
power. (2) There are too many logical inconsistencies that such
a treatment would impose on the learning situation. How much of
the above-mentioned reduction in auditory feedback can be affected
without destroying the intent of the experiment?

2.2.3.6 Language-laboratory control: II. The above considerations
led us to the decision to use a single control group whose treat-
ment can be characterized as follows: identical to the experi-
mentals', save with no visual feedback to aid in pronunciation
improvement.

Since our system was designed to act as an adjunct to the language-
laboratory paradigm, it contains within itself the essential op-
erations of that paradigm along with its crucial innovation. If
we cannot accept a treatment as described in Section 2.2.3.4, we
can at least approximate it within the limited training regimen
envisioned for the experiment. We can allow S to listen to record-
ings of single words, to mimic these, and to listen to recordings
of his efforts. We can then instruct him to try to correct any
pronunciation problems on his own, with no visual feedback and no
monitoring. While the specific properties of the experiment—its
limited set of trained utterances and the techniques of evaluation

to be described below—may make this control treatment different
from and perhaps even superior to the standard language-laboratory
paradigm, this treatment provides the single most clearcut test of
comparability with extant techniques and was adopted for reasons
of experimental efficiency.

2.2.4 Outline of the Experiment

Having described the capabilities of the system and the reasons
leading to the choice of the control treatment, we turn now to a
consideration of the overall structure of the planned experiment.

2.2.4.1 Subject selection. Advertisements were placed in local
newspapers, store-fronts, and college employment agencies, inform-
ing Spanish-speaking persons of the availability of a course in
English pronunciation improvement. When they contacted us, we
arranged an interview. At that time, they were asked to repeat
a series of English words after the interviewer; then, usually with
consultation with other members of the research team, a decision
was reached as to whether the speaker possessed the type of English
pronunciation problems that our system was designed to help. Po-
tential Ss also filled out a form giving an individual linguistic
history, for use in matching exposure to English in experimental
and control groups. As a first step, two experimental and two con-
trol Ss were selected and matched by this procedure, and they were
run through the beginnings of the experiment described here. As
things developed, however, this experiment was terminated early
and labeled a "pilot experiment" for reasons discussed below in
Section 2.4.

2.2.4.2 <u>Stimulus material</u>. In its present form, the system is
designed to aid in the improvement of intra-verbal parameters of
speech, and is not sensitive to prosodic features. For this reason,
and since the words surrounding a given word in an utterance affect
its acoustic properties, the stimuli used in the experiment must
be utterances of single words. Further, since we wish to evaluate
the efficacy of three separate displays in changing different ar-
ticulation parameters, we needed stimulus words appropriate for
each of the three planned displays. The three lists should contain
words which the <u>S</u>s pronounce with some degree of difficulty, which
are relevant to the particular display, and which otherwise present
no major pronunciation difficulties for them. Tables 2.1, 2.2,
and 2.3 contain the lists compiled with these considerations in mind.

Table 2.1 contains 48 words, four for each of the 12 English vowels
being studied. Their consonant environments have been balanced as
follows. First, the words were selected so as to minimize the con-
sonant pronunciation difficulties of the <u>S</u>s. Half of the initial
consonants are voiced and half are unvoiced. After the vowel sound
of the word, 6 words are open; 24 close with voiced consonants; and
18 close with unvoiced consonants. These are randomly distributed.
Sets 1 and 2, which have initial consonants all voiced and all un-
voiced, respectively, are designated the "critical set" and are
discussed in that capacity in Section 2.2.4.3 below.

As mentioned above, <u>S</u> works with all 12 English vowels during one
session. He does this by working through a list of 12 English words,
one per vowel, drawn from the above sets. The main reasons for pre-
paring more than one word per vowel are to provide variety for the
<u>S</u>s during their training, and to attempt to ensure that new pronun-
ciation habits are not limited to just one overlearned word per

Table 2.1 Vowel Words

		Set 1	Set 2	Set 3	Set 4
		Critical Set		Additional Training Set	
1.	i	BEET	FEED	SEE	FEET
2.	e	DAY	FACE	SAFE	PHASE
3.	a	GOT	SOB	DOCK	GOD
4.	o	BOAT	SEWED	SO	DOSE
5.	u	BOOT	FOOD	DO	BOOED
6.	ɪ	BID	SIT	BIT	FIB
7.	ɛ	DEAD	SET	FED	SAID
8.	æ	BAD	SACK	DAD	SAG
9.	ʊ	BOOK	TOOK	SOOT	GOOD
10.	ʌ	BUT	FUSS	BUG	BUD
11.	ɚ	BIRD	SIR	FUR	BERT
12.	ɔ	DOG	SOUGHT	BOSS	SAWED

19

vowel. To spread the practice on the "critical set" of 24 words
over successive sessions, four lists of words were prepared from
the contents of Table 2.1.

        List 1: Set 1, vowels 1-6; Set 3, vowels 7-12
        List 2: Set 1, vowels 7-12; Set 3, vowels 1-6
        List 3: Set 2, vowels 1-6: Set 4, vowels 7-12
        List 4: Set 2, vowels 7-12; Set 4, vowels 1-6

It thus takes a given S four training sessions to be exposed to all
48 words. The physical form of each of the four lists is four
stacks of Language Master (LM) cards, each coded as to set of ori-
gin, with a recording of a teacher's voice speaking each of the
words. The order of vowels within each list is random and differ-
ent for each list, and the cards are numbered to maintain that
order throughout training. The S is given one of these stacks of
cards at the outset of each session, and works with it cyclically
for the duration; that is, he returns to word 1 after completing
activity on word 12, and may go through the stack as many times as
he wishes.

Dennis Klatt, whose English pronunciation is "General American,"
recorded all the LM cards used as stimuli. All recordings were
checked for fidelity, phonetic accuracy, and constant subjective
volume.

Tables 2.2 and 2.3 contain words relevant to the reduced-vowel and
aspiration displays. LM cards were prepared with these words, though
the actual displays had not been developed and they would not be
studied by the Ss at the outset of the experiment. Since the plan
is to incorporate those displays into the ongoing training regimen

20

Table 2.2   Reduced-Vowel Words

Stress 1--	Stress 1-3	Stress -1-
DIFFICULT	EXECUTE	DISTINGUISH
FEASIBLE	MODIFY	SPECIFIC
	PHOTOGRAPH	
	MEDITATE	
	TESTIFY	

Table 2.3   Aspiration Words

CUB	PEACE	TEASE
CUT	PEAK	TEACH
CUSS	PEEL	TEA
CUP	PEER	TEAM
KEEP	PUN	TOUGH
KEY	PUNCH	TOUCH
KEYS	PUP	TON
KEEN	PUB	TUB

built around tongue-position, we had to plan for their inclusion
according to the requirements of the experimental design. Thus,
Tables 2.2 and 2.3 are also part of the "critical set" and will be
discussed in that capacity now.

2.2.4.3 <u>Testing and evaluation</u>. The method used to evaluate
changes in speech as a function of training is crucial to the ex-
perimental design. We plan three tests and two types of evaluation
of the data arising from those tests. The tests will be <u>identical</u>
in format, and will occur: (1) at the beginning of training; (2)
immediately following the conclusion of training; and (3) follow-
ing a one-month retention period with no intervening treatment.
These tests will be referred to as pre-, post-, and retention tests.

As carried out in the pilot experiment, the pretest had the follow-
ing format. S would enter and be introduced to the machine. This
was usually a laborious process requiring time and demonstrations
by the experimenter (E), since in many cases the pilot S's com-
prehension of spoken English was fragmentary. Following this, S
was seated before the apparatus and all subsequent utterances were
recorded on the history tape for later analysis. There was no
articulatory feedback from the CRT at any time during the test, for
either experimental or control Ss. S would first execute the nor-
malization section, speaking 5 Spanish words. Then, S was asked to
utter a total of 57 English words in the following manner. Each
word was written and recorded on a separate LM card. E, who was
sitting in the room beside S, entered the card into the system and
S heard it as it was recorded on the tape loop and read it from the
card. S then pressed the STORE button, heard the teacher speak the
word, got the prompting signal from the CRT indicating that the
microphone was on, and spoke the same word immediately afterward.
This finished the work on that word, except in the case where S spoke

22

in such a manner that the program detected an error in the speech
input of one or more of the following types: too soft; too loud;
begun too late in the time window; or too short total duration
(e.g., a transient).   Note that none of these criteria refer to
pronunciation.   If such an error occurred for a given recording
attempt, the CRT displayed the word REPEAT and S̲ was asked to re-
peat the process with the STORE button.

The first 9 words recorded in this way were the reduced-vowel set
shown in Table 2.2; these were followed by the 24 "critical" vowel
words in Table 2.1; and the last 24 were the aspiration words.
This order of procession through the word types later proved not
to be opportune, and it was changed in the ongoing version as dis-
cussed below in Section 2.5.2.3.   Within each of the word types,
the order of presentation was random and different for each S̲.   The
plan is to use the same random order for the same S̲'s post- and
retention test.

Following the recording of the 57 English words, S was asked to sight-
read a short English prose passage.   We felt that despite difficul-
ties caused by unfamiliar orthography, such a recording would be
useful in that it provided a standard connected utterance which
could be investigated as a function of training.

We have now described how all S̲s will be treated on the three test-
ing days, and the kind of data gathered on those days.   We have also
described the main features of the training that will intervene be-
tween pretest and posttest, at least insofar as it has been developed
for the tongue-position display in vowel pronunciation.   Let us re-
call that control S̲s will receive identical treatment to the exper-
imentals, save with the omission of all aspects of articulation feed-
back.   We proceed now to a discussion of the planned methods of data
analysis.

The first method of analysis we plan is a subjective rating tech-
nique. We will have recorded three versions of several English
words at different points in time. It is a simple, though labori-
ously time-consuming, job to construct a tape by the dubbing pro-
cess containing the various utterances by the various Ss in a
random, counterbalanced order. We plan to play this tape for a
group of English-speaking judges, who will assign an accent rating
to the utterances according to criteria yet to be specified. By
reference to the treatment accorded a particular S and the knowl-
edge of when the utterance was made, we shall be able to quantify
and statistically evaluate any changes which occur as a function
of time and treatment, given the pretest data as a baseline. We
also contemplate the possibility of employing more sophisticated
pair or triad comparisons on the recorded utterances. Final plans
for subjective data analysis are still fluid, there being no urg-
ency about the decision as long as procedures for baseline data
collection are compatible with all of the analysis procedures
being considered. This is of course the reason for the presence
at the pretest session of utterances relevant to reduced vowels
and aspiration. Upon development of reduced-vowel and aspiration
displays and their incorporation into the training procedure, we
shall use the contents of Tables 2.2 and 2.3 as the core of the
training stimuli. At that time, we may decide to use more words
in the training than those recorded on the testing days; but at
least we shall have an adequate sampling of pretraining performance
available for use as a baseline. Considerations of dubbing time
and judgment time by the accent raters led to the decision to
place an upper limit of 24 on the critical set for any display.

There may be insufficient time to carry out a second planned
method of data analysis, but the testing sessions are designed to
make it possible. It would be most instructive to make an acoustic

24

analysis of any changes in the utterances as a function of treat-
ment and time, in the same way as the subjective analysis described
above. The most straightforward way to accomplish this is to use
the capabilities of the present system, which can plot representa-
tions of sound spectrograms and display derived measures on the
CRT as part of its feedback algorithms. What is required is a re-
cording of S's voice in an order of utterances intelligible to the
system, and a version of its software which will enable E to in-
spect parameters of a given utterance at his leisure. In the case
of the tongue-position display for vowels and reduced-vowels, the
recording must also contain the 5 Spanish words for the purposes
of normalization of the target positions. This is why the normali-
zation is included in the testing sessions, even though no articula-
tion feedback appears on the screen. And the fact of no feedback
at the time of recording necessitates the later provision of a way
to inspect the feedback which would have occurred, if the effect
of each display in training is to be evaluated according to its
own logic.

It is a simple matter to construct the tapes and produce the soft-
ware necessary for production of 19-bin sound spectrograms or ar-
ticulation displays for each of the words on the tape. The acou-
stic analysis might then take the form of standard formant plots
and the like, or it might utilize the displays to calculate per-
formance parameters peculiar to the logic of the particular dis-
play. For example, an interesting statistic for the vowel display
would be some measure of discrepancy between vowel trace and target
as a function of treatment and time.

2.3 SYSTEM MODIFICATION: PHASE I

We have discussed the aims and design of what was to become the
pilot experiment for the current work. In many instances, this has

25

required mention of particular system configurations different
from those described in previous reports. This section's purpose
is to explicitly define the changes made in the apparatus and pro-
cedures for that pilot work, and to explain the motivations for
those changes.

2.3.1 Human Engineering

The task confronting the naive Spanish-speaking S in learning to
use the system is highly complex and much more intimidating than
it is to a technically trained speaker of English. In the pilot
experiment, we tried to ease the burden by extensive demonstra-
tions with a research assistant acting as S, and with a one-page
English-language key to the functions of each of the buttons on
the button-box. This turned out to be insufficient and one of the
main stumbling-blocks to the completion of the experiment.

In the actual operation of the system, there were several buttons
which S could press, and the CRT could display a variety of dif-
ferent messages. We tried to simplify these as much as possible.
Appendix A contains the text of the English instructions given
verbally to each S in the pilot experiment, explaining the func-
tion of each of the buttons on the control panel. Note the fol-
lowing things for future reference.

1. S says the 5 words in Part I only once.

2. In Part I, S is expected to keep his place in the list solely
    with the aid of the number of the word appearing in the lower
    left corner of the CRT, and with no auditory feedback from a
    teacher's voice as provided in Part II.

3. The training instructions for the control Ss omitted reference
    to tongue-position feedback, and the large rectangle on the
    CRT was always empty for them. This rectangle was also empty
    on all Ss' testing days.

26

4. This is relevant not only to the training procedure, but also
    to the testing procedure. S always utters his version of the
    English word <u>immediately after</u> hearing the teacher's voice.

In summary, the first phase of human engineering resulted in a
system rather more cumbersome than the present version described
below, in Sections 2.4 and 2.5. We shall now discuss the under-
lying changes introduced to serve the experimental design, and
show how these are reflected in testing, training, and analysis.

2.3.2 <u>Software Modifications</u>

The first modification required by the experimental design was the
capability for a control version of the program. This was effected
by the reading of a switch on the register of the PDP8/1. When
this switch was set in the control position, the feedback rectangle
on the CRT was always empty, and pressing BUTTON #1 did not result
in continuous-picture feedback. This procedure was used at pretest
sessions for all Ss, and during training for control Ss.

Since there were four different lists of words used during the
course of vowel training, the system needed a method of keeping
track of which list S was working on at a given session, and which
word was being studied at any given time. The problem is especially
acute since the order of vowels differs between lists, since the
correct target must be presented on the CRT for each of the 12
words, and since the core storage of the machine is limited. This
problem has been solved through the use of four separately loadable
versions of the program stored on a high-speed magnetic tape reader.
When list N is required for a given session, its version is quickly
called into core; and then, as the session progresses, the program
will display the correct target for each LM card in the stack of

12, along with the word number which $\underline{S}$ is told to maintain in agreement with the word number on his current card. It has unfortunately proven impossible to have the CRT display the text of the word in place of its number in the list; core limitations force a compromise which causes occasional confusion.

Such strict attention to maintaining word numbers in agreement might seem superfluous in the case of control $\underline{S}$s, who after all receive no feedback based on the particular word they utter. But if we are to study the fine grain of $\underline{S}$s' behavior as they are trained, we need information about relative demands on the system for each of the vowels, for both experimental and control $\underline{S}$s. This type of information can give insights into utilization patterns as a function of time and treatment, and is indispensable in designing a time-shared analog of the present system for handling more than one $\underline{S}$ simultaneously. We therefore made provision for the recording of the following 5 data for each of the 12 words in each list:

1. Number of times $\underline{S}$ pressed STORE throughout the session. This gives an indicant of the total number of times $\underline{S}$ heard the teacher and followed this by an utterance of the same word. This is sometimes unsuccessful in producing feedback for both experimental and control $\underline{S}$s, when one of the error criteria mentioned in section 2.2.4.3 is met and the CRT says REPEAT.

2. Number of times RECALL is pressed. An index of the care with which $\underline{S}$ listens to any differences between his and the teacher's voice.

3. Number of times BUTTON 1 is pressed. The only time a control $\underline{S}$ presses BUTTON 1 is to ask for help, and so this and items (4)

and (5) are not of any use for control Ss' data. For experimentals,
it is an indication of the number of separate times they entered
continuous mode throughout the session. Note that items (1)
through (5) cumulate all activity in successive passes through
the stack of 12 words, collapsing it onto individual words and
sacrificing information about the time course of usage within the
session.

4. When the system is in continuous mode, it "listens" to the
microphone until it detects a sound above a certain level, and
then it records a maximum of 50 samples spaced 10 msec apart (or
one-half second total) and displays inferred tongue-position
points on the screen. A continuous utterance exactly 2 seconds
long will thus be subdivided into four "utterances" whose 200
points will be cast on the screen in four groups, each group being
supplanted instantly by the following one. Four separate utter-
ances, each 100 msec in length, will be counted as the same number
of utterances, but the total number of points cast on the screen
will only be 40. The fourth item recorded is thus the number of
separate utterances made within a given word. Since the English
words used all require less than one-half second to speak, and
since the Ss were told to experiment with this mode using single
words and/or isolated vowel sounds, this count will give a rough
idea of the number of separate words uttered by S in continuous
mode during the course of his work on a given LM card.

5. A cumulative count is also made of the number of points thrown
on the screen, as described above. If this number is 753, this
means that 7.53 seconds of speech were analyzed by the machine
for a given word in the session.

The following three data refer to the conduct of the session as a
whole, and not to the behavior of S within each word.

29

6. Within Part I: number of times BUTTON 8 is pressed to correct
some error in the utterance of one of the Spanish words. An index
of difficulty in passing through this section.

7. Across Part II: number of times S pressed BUTTON 6 to enter a
new LM card.

8. Across Part II: number of times S pressed BUTTON 7 to correct
errors of disagreement between word numbers on LM card and CRT.
Subtracting (8) from (7) will give a rough idea of the number of
times S passed through the list during the course of the session.

These data are preserved for later analysis by means of a routine
contained in each of the four versions of the program that punches
a paper tape containing identification information and list number,
followed by all data mentioned above in a standard format. We plan
to write a collection, filing, cross-referencing, and analysis
system for the data using our larger PDP-10 system. This will
enable us to pinpoint the vowels with which Ss spend most of their
time, and how they attack the problem. It will also allow compari-
sons between experimental and control Ss' behavior and between
effort in training and outcome as defined by the evaluation tech-
niques discussed in Section 2.2.4.3.

2.3.3 Phonology-Oriented Modifications

Previous reports have described in detail the theory, hardware,
and software underlying our approach to the display of inferred
tongue-position in vowel pronunciation. Briefly, a 19-channel
filter bank representation of a sound spectrogram is constructed
for each analyzed utterance, with values stored in computer memory
each 10 msec during the speech. These digital values represent the

logarithm of the energy present in each bandpass filter at a
particular instant of time. The ideal system would, at this point,
apply curve-fitting or formant-tracing algorithms to the vowel
portion of the data. Each time sample would thus yield values of
F2 and F1 to serve as X and Y coordinates of a point in the tongue-
position display. Because of limitations of storage space and
computation time, the present system utilizes simple addition and
subtraction algorithms which have been empirically tuned to pro-
duce values having many of the same properties as F2 and F1, but
in a shorter time. These are called the front-back and height
functions. Because these algorithms are simple sums and differ-
ences of specific filters, and because of the inevitable individual
differences between speakers, the following complications have
ensued.

2.3.3.1 Restriction to female Ss. The smaller vocal tracts of
females shift all the resonances so important for vowel production
upward by about 25%. Therefore, there is no general algorithm for
simple addition and subtraction of specific filters which will
behave identically for both male and female Ss. Storage limita-
tions precluded the addition of an input parameter specifying the
sex of a given S, and so the sample for this experiment was drawn
from a single sex rather than write two separate programs for the
two sexes. Females were chosen on the basis of greater availability
in the local population.

2.3.3.2 Multiple front-back functions. It developed that there
was no single algorithm that could adequately produce a reliable
X coordinate for the display for both front and back vowels. We
therefore developed three separate functions, each covering a
specific subset of the 12 English vowels. When S works on a given
English word on his list, the computer applies the appropriate

31

front-back algorithm to the display, and the trace of tongue posi-
tion is given in terms appropriate for the target displayed.
Appendix B gives the specific algorithms described in Section 2.3.3.

2.3.3.3 <u>Speaker-normalization procedure</u>. This has been briefly
described in Sections 2.2.1 and 2.2.4.3 above, but its rationale
has not yet been presented. We are attempting to expand the vowel
repertoire of our Ss from the original five tense Spanish vowels
to a larger set of twelve English vowels. Of the twelve, five are
similar to their Spanish counterparts. A Spanish speaker with a
strong vowel-pronunciation problem will try to substitute one or
more of these original vowels, or occasionally a consonant variant,
for the remaining seven. We are attempting to produce new patterns
of tongue movement by displaying targets for those vowels that are
in different positions than the original five, and providing feed-
back to aid the S in hitting those targets. Locating those twelve
targets is thus a twofold problem: accounting for individual dif-
ferences in vocal tract acoustics, and specifying the locations of
intermediate points.

During Part I, when S speaks the five Spanish words sisa, peso,
padre, cosa, and su, the vowel sections of the first syllables of
those words are stored in memory, and the middlemost time sample
of each syllable is treated by the height and the three front-back
algorithms, yielding tongue-position coordinates for those syll-
ables. The appropriate front-back value is chosen for the balance
of the analysis. Thereafter, the targets for English words having
those five vowels are placed according to the data gathered in the
initialization utterances (with offset factors as discussed below).
The targets for the balance of the English vowels are positioned
by means of computations involving combinations of the original
five, which are taken as standard positions corrected for individ-
ual differences. Thus, individual differences are accounted for

32

by fitting the target locations for the five original vowels to
the utterances of S; and the locations of intermediate targets
are determined by computations based on those standardizing
utterances.

The following additional modifications were introduced for reasons
different from those mentioned in the introduction to Section
2.3.3.1.

2.3.3.4 _Target offsets_. The tongue trace of a set of monosyllabic
English words with the same vowel will depend on the consonant
environment of the particular word. For example: If the initial
consonant has left the tongue in the front of the mouth, the vowel
trace will be more forward than if the initial consonant had placed
the tongue elsewhere. Consonantal conditioning occurs in both
forward and backward senses, in that the trailing consonant can
also exert an influence. Since there were four training lists for
vowels, and thus four different English words containing each
vowel, the specific effects of consonantal conditioning needed to
be quantified for each, if target location was to be valid for the
word in question.

The following procedure was used to quantify and correct the prob-
lem of consonantal conditioning. Five female employees of Bolt
Beranek and Newman Inc., all native Americans, served as speakers.
Each S completed Part I by speaking the English words beet, bait,
pot, boat, and boot — the same vowels used by the Spanish speakers.
Any differences in the English and Spanish vowels were taken into
account in subsequent data analysis. S then proceeded to speak
all 48 English words in the four lists, using the STORE button as
outlined above. The E sitting beside them, would then make a free-
hand sketch of the location of the tongue trace with respect to a

target box contained on a prepared targeting performance test
blank. Two acceptable utterances o.' each word were made and
sketched. The data were then collapsed across Ss and within words,
to see if there was any consistent trend in a particular direction
away from the target. If the traces for all or most of the 5 Ss
moved appreciably for one word and not another, the target's loca-
tion for the word in question was adjusted by a small offset factor.
Each offset factor for a given word was applied in the following
manner. When S is to work on a particular list for a session, E
loads the version containing information regarding the order of
vowels and targets in the stack of LM cards given to S. The gen-
eral location of each of the 12 targets is determined by the nor-
malization data and by the computations based on them. But there
may also be an offset factor contained in a given version, chang-
ing the general, theoretical location of a given vowel's target to
take account of the consonantal conditioning that the particular
word imposes on the tongue trace of the vowel.

2.3.3.5 <u>Differential target size</u>. The above-mentioned work with
the five English-speaking Ss confirmed and quantified a notion we
had begun to formulate on the basis of informal pilot work. Intra-
and inter-speaker differences in the utterance of acceptable ver-
sions of English words may be observed in the vowel traces, such
that small targets might be spuriously difficult to hit. The tar-
gets needed to be small enough to delimit the region of acceptable
pronunciation from the regions of accented pronunciation, yet large
enough to encompass the variability inherent in acceptable pronun-
ciations. The normal target configuration had been a 1 cm square
on the CRT. This was changed to a 1-cm high x 2-cm long rectangle
for the vowels I, ɛ, u, and ɚ, and to a 1-cm high x 3-cm long rec-
tangle for the vowel æ. These shapes were constant for all four

34

lists; the locations of their central points were determined by
the algorithms outlined in Sections 2.3.3.3 and 2.3.3.4. Ss were
told that to hit the target with the vowel trace was better than
not hitting it at all, and that to make the trace pass through the
center of the target was a desirable, though sometimes unattainable,
goal. Details of these instructions were given verbally to Ss in
the pilot experiment.

2.4 THE PILOT STUDY AND THE PROBLEM OF MIMICRY

We began formal work with an original group of 4 Ss, two experi-
mentals and two controls. As we carried out the pretesting and
first few training sessions for these Ss, our intention was to main-
tain the screening interview process with the continuing flow of
potential Ss which our advertising campaign had begun. Our inten-
tion was to add Ss to our groups until a full complement had been
reached. Two problem areas, one minor and the other major, halted
the progress of this experiment and forced major reassessments and
modifications of the system.

2.4.1 Human Engineering

The minor problem area for the experiment was a result of apparatus
and situational difficulties. Despite our efforts to convert a re-
search-oriented system suited for technical personnel to an apparatus
useable by inexperienced Ss, the result was a situation in which
those Ss were prone to make errors in issuing commands to the com-
puter and in which their instructions for usage and interpretation
were insufficient for the task. The procedural, software, and in-
structional problems were isolated and their solutions are described
below in Section 2.5. It would have been possible to continue the

35

experiment in the face of the human-engineering difficulties which
became apparent, although it would not have been advisable. The
problem which could not be circumvented by additional training and
instructions arose from a more basic source.

2.4.2 Mimicry

One of the reasons we had started with so few Ss was that they were
hard to obtain through the screening procedure outlined in Section
2.2.4.1. The interviewer spoke English words and phrases, and S
repeated them immediately. The amount of accent apparent in those
utterances was used as a criterion for admittance. In addition to
the unspecifiability of that procedure as an operation, it suffered
from a shortcoming which was also obvious in the performance of the
Ss we had selected and were already running. Ss with severe ac-
cents in normal speech could perform quite well in the listen-to-
teacher and repeat mode, or mimicry mode. Some Ss we had already
selected and whom we were running seemed to speak better in train-
ing than we had anticipated from the screening; and we screened
many Ss possessing strong accents in normal conversation who per-
formed admirably in mimicking the utterances of the interviewer.
We found this mimicry capability in a large proportion of the screen-
ing Ss, until we were forced to realize that either our admission
criteria were too rigid, or that the apparatus was designed to aid
pronunciation problems that are rare in the population of Spanish
speakers. We knew that the latter was impossible, given the severe
accents audible in their self-generated speech, and it became clear
that we were selecting Ss on the basis of a subsystem of vocaliza-
tion—mimicry—rather than on the basis of normally emitted speech.
We needed a modification which would force Ss to emit rather than
mimic speech, and which would permit the use of the system's hard-
ware and basic software in the new situation.

36

The issue was a complex one, since speech <u>emission</u> is normally a
free-form affair in which the speaker extemporizes. The require-
ments of the system and of the experimental design are far more
stringent. The main stumbling-block is the requirement that cer-
tain specified English words must be spoken and recorded in test-
ing accent changes over training and treatment, and that the ap-
paratus can respond only to single-word utterances during training.
Even if the desired English words could be spoken in connected
speech on testing days, detailed acoustic analysis of the words of
interest would be contaminated by suprasegmental effects on the
acoustic properties of a given word. A further problem arises
if an attempt is made to have Ss speak the same English sentences
during testing, to try to ensure that at least the suprasegmental
context of a given word will be constant across testing time: the
only way to achieve this is by requiring S to read the English text,
which is bound to produce orthographic mispronunciations. There-
fore, the training and the crucial testing procedure must be done
with single-word utterances, but in a manner approximating normal
emission as far as possible.

After recognition and discussion of the above two problem areas, the
experiment then in progress was terminated. The four Ss had passed
through five sessions each of the experimental procedures: one pre-
test day and four normal training sessions. They were told that
the equipment needed repairs, paid and thanked for their services
thus far, and dismissed. The following section details the changes
made before the initiation of the experiment now in progress.

2.5 SYSTEM MODIFICATIONS: PHASE II

2.5.1 Inversion of the Order of Speech

This section describes the rationale for the major difference be-
tween the pilot experiment and the one now in progress. We reasoned
that there was a short-term storage of the sound of an English word
which enabled the Spanish speaker to imitate it if there were no
appreciable delay; but if she must initiate the utterances of the
whole word with nothing in the short-term store, then she will make
the mis-articulations and substitutions characteristic of her ac-
cented speech. The problem is thus to maintain single-word utter-
ances in a situation providing freedom from orthographic as well as
mimetic contamination. Our approach to its solution was to allow
S to hear the teacher's voice only after having spoken the English
word. This decision had ramifications for both the training and
testing sessions' design.

2.5.1.1 Training session configuration. Part I, where S speaks
Spanish words, is unaffected by the modification since S does not
model her speech after a recording, but only after her own correct
Spanish pronunciation. In Part II, S uses the following procedure
to record a test utterance on the tape loop. Pressing the STORE
button immediately turns on the microphone, puts a "GO signal" on
the CRT, and enables recording on the tape-loop and tape-history
recorders. These conditions obtain for 1.7 sec, during which time
S is expected to utter the word contained on her last-entered LM
card. If she does this within certain ranges of volume and onset
time, she is "rewarded," upon cessation of the time window, with
two things. The display illustrated in Fig. B-1 of Appendix B re-
turns to the screen, containing the word number at the lower left,

the current target, and the inferred trajectory of her tongue dur-
ing the vowel portion of his immediately preceding utterance. Si-
multaneously with the return of the display, playback on the tape
loop is enabled, and S then hears the recording of the teacher's
voice which was transferred to the loop from the current LM card.
When the teacher's utterance concludes, the loop is stopped and
the + reappears at the lower-right corner of the CRT, indicating
that the system is ready for new commands. S is then free to issue
any command. If RECALL is chosen, S will hear the contents of the
loop: her voice, and then the teacher's voice. She may then immed-
iately initiate another STORE command, and thus utter the word im-
mediately after having heard the teacher's voice.

If S fails to meet the timing and volume criteria in making her STORE
utterance, the following "punishments" occur. Upon cessation of
the time window, S is not permitted to hear the teacher's voice.
In addition, when the display returns, the trajectory is absent and
the word REPEAT appears between the word number and the position of
the ready signal. S must wait in silence for a time equivalent to
that used by the recording of the teacher's voice, and when the +
reappears, the only command open to her is STORE. She may not RECALL
the contents of the tape loop, she may not press BUTTON 6 to begin a
new LM card, and she is told not to use BUTTON 1 for continuous-
feedback mode. Therefore, her speaking behavior in STORE is gradu-
ally shaped under these response contingencies until it is com-
fortable and stereotyped. After several initial blunders, Ss exper-
iences few unsuccessful STORE attempts.

2.5.1.2 Testing session configuration. The above procedure has
the effect of ensuring that Ss initiate the speech sequence during
training. If S spends some time in considering the information

contained in the display resulting from a STORE or in listening
carefully to differences between the voices heard in a RECALL, her
speech in the next STORE will be sufficiently far removed in time
from her last hearing of the teacher's voice so as to be uncontam-
inated by the mimicry effect. The time interval is not strictly
controlled in training for fear of constraining Ss in their usage
of the system. In testing, however, more care must be taken. We
must balance the need to avoid mimicry with the need to avoid ortho-
graphic contamination of the test utterances. That is, we cannot
expect Spanish-speaking Ss to be able to read English words and to
use that information to produce their best approximations to English
pronunciation. They must hear a correct pronunciation so that their
misconceptions about the letters are removed; but the effects of
this hearing on their subsequent utterance must be minimized.

This has the following effect on the paradigm used on testing days.
Part I is still unaffected. In Part II, there are still no targets
or trajectories seen by either experimental or control Ss. Each of
the 57 test words on the LM cards is treated in the same way. The
monitor (E), seated in the room with S, enters the new LM card into
the tape loop. On testing days as on training days, nothing is heard
in the room during this process, a change from the original config-
uration. S is then able to press STORE and speak the word. This
utterance is usually contaminated by orthography, since S's only aid
in pronunciation is the printing on the corner of the LM card and
her own experience with English. If the utterance meets the criteria,
S then hears the teacher's voice speaking the word for the first time.
At the lower-right corner of the display, the figure 8 also appears
immediately. This number is successively decremented at a rate de-
termined by the display logic. When the loop stops moving—the time
when the + would normally reappear—a clock is set by the program.

40

The countdown proceeds, reaches 0 or 1, and 4.096 sec later the + reappears in place of the countdown. S then presses STORE once more and speaks the same English word, but having heard it once and having waited a predetermined minimum time. That concludes the work with each LM card, if both STORE utterances were acceptable to the timing and volume criteria.

If an utterance is unacceptable, the word REPEAT appears on the CRT. S hears nothing from the tape loop, and she must wait for the countdown to conclude before the machine will allow her to proceed. This has the following logical effects in addition to the shaping effect mentioned in Section 2.5.1.1. If the first one or two STORE attempts for a given word are unsuccessful, then the first successful attempt will be followed by the first hearing of the teacher's voice. If the next is unsuccessful, the number of hearings of the teacher will be held to one before the next successful utterance. The second successful utterance of the test word is the version of interest, the one which will be analyzed subsequently. Ss are told not to worry about their pronunciation of the first utterance, and to try to get their second one to sound as much like the teacher as possible. Only if S felt she made an obvious mistake or if E detected an artifact in the second successful utterance was a third one attempted. Through this whole procedure, the RECALL button and the continuous-feedback buttons are disabled. S therefore never hears any recordings of her voice during testing, and of course never receives any articulatory feedback.

The two-utterance paradigm with countdown has the following effects on mimicry. After hearing the teacher's voice, S must wait a predetermined time before being able to emit the sounds she has heard. The sheer delay itself would have an adverse effect on the short-term

41

mimicry storage; but this is further complicated by the presence
of the countdown. S must look at the numbers as they decrease if
she is to wait a minimum time. Since the final number to appear
may be either 0 or 1, the particular number on the screen gives no
fine-tuned cue to expected ready time. S must wait and make the
final discrimination about whether or not the + has reappeared be-
fore the machine will again respond to a STORE request, and mean-
while the countdown is dragging the Spanish equivalents of "...
three, two, one,..." through her consciousness. Only after this
is done can she start the speech-emission process again, reading
the word and utilizing the remembered sounds of the teacher's voice.
This is still not true speech emission, but it represents the best
compromise we have devised for the situation.

2.5.2 Other Situational Modifications

2.5.2.1 Instructions. The major addition to the current experiment,
aside from the inversion of speech order, is the presence of exten-
sive Spanish-language written instructions. These were written in
simple English, translated commercially, and checked for technical
and idiomatic accuracy by two Spanish-speaking scientists at Bolt
Beranek and Newman Inc. The detailed instructions cover basic
orientation to the system and complete descriptions of procedures
used on testing and training days for both experimental and control
Ss. The latter Ss' instructions deleted all references to the dis-
play of articulatory features. There is also a one-page outline of
the session containing a brief description of the functions of each
button. Each of the components has a small sign, in Spanish and
English, containing crucial information which Ss need constant re-
minders about to minimize errors. Each S receives a copy of the
appropriate detailed and summary instructions for her own study at

home, and a copy is always present in S's room during training.
Appendices C and D contain the English and Spanish versions of
these instructions, with Appendix C indicating which sections appear
during testing and training sessions, and where the deletions and
substitutions for control Ss are located. Appendix C also contains
the figure placed above the loudspeaker for experimental Ss on
training days, indicating orientation of the display rectangle in
the mouth. Appendix D contains the same text material in the same
order, but minus the notes and the figure.

Additional written material is given S on each training day. With
the stack of 12 LM cards, S receives a mimeographed sheet with the
12 words written on it in order of occurrence in the list. Follow-
ing each English word is a short Spanish translation of the word,
covering just one of its English connotations (e.g., "set" is trans-
lated "colocar," in the sense of "to place"). This translation is
provided to provide some meaning for the sound S is trying to make.
S is told that she may use the sheet for whatever purpose she de-
sires during the session—to indicate words she is having difficulty
with, to use written mnemonics for pronunciation, for nothing, etc.
Appendix E contains the English words and their Spanish translations,
and incidentally records the contents and order of the $^\mu$ vowel-
training lists.

2.5.2.2 Modifications to Part I. Three modifications designed to
minimize errors in normalization have been introduced. In place of
the word number at the lower left of the display, indicating to S
which of the 5 Spanish words she is working on, the word itself now
appears. Thus, when a mistake is made, the screen will read, e.g.,
"PESO REPEAT +" and S knows just which action is expected of her.
If the screen says, e.g., "PADRE OK +," S then refers to her in-
structions for the next word she is to speak.

43

The time window available to S after she presses BUTTON 8 or 9
has also been increased from its length in the previous experiment.
Whereas before it was identical in length to its value in Part II,
it has been increased to 3 sec, minimizing frustrating and anxiety-
provoking rejections. Since the utterances in Part I are of crucial
importance to the displays in the session for the experimental Ss,
and to the acoustic analyses of the test sessions for all Ss, it is
essential that S's anxiety level be kept as low as possible, to
facilitate normal, correct Spanish pronunciations.

The final modification toward this end is the repetition of the
list. The first pass through the Spanish words serves to accli-
matize S to the equipment. This is very helpful during the pretest
session, when S is usually nervous about using the apparatus for the
first time. During training sessions, it serves a similar though
less crucial function. Then, the data from the first pass are dis-
carded, and the utterances made during the repetition of the list
are used as the basis for any displays in the session.

2.5.2.3 Modifications to testing procedures. The order of passage
through the critical word lists was changed. Each of the three
lists of words was pronounced, in a different random order for each
S, as described above in Section 2.2.4.3 and amended in Section
2.5.1.2. However, the first words used were drawn from the aspir-
ation list; following these 24, the 9 reduced-vowel words were spoken;
and the 24 critical-vowel words were spoken last. By the time the
Ss reached the vowel words, they were quite proficient at using the
equipment, and experienced little difficulty in progressing through
the words crucial to the most important section of the experiment.
Since we will be devoting the most training time to the vowel words,
we felt that the words testing the effects of such training should
be collected under the most advantageous conditions.

Following Part II of the testing-day procedure, S was asked to read
a prose passage; this too was changed from its pilot version. Where-
as before S sight-read the passage, this was deemed too stressful
and too prone to orthography errors. Presently, E hands a page
containing the material to S, and reads it slowly to her while she
follows silently. This is repeated. Then S records the material.

In an effort to simulate normal speech conditions but still to main-
tain some control over the speech material spoken, an additional
page of written material was read by E and repeated, sentence by
sentence, by S. Appendix F contains the first prose paragraph,
called the "rainbow passage," and the second sheet of sentences.
The first group of sentences are built around the list of aspiration
words; the second, around the reduced vowels; and the third, around
the vowels. It is expected that the lack of strict temporal control
during the reading-repeating cycle will promote spurious mimicry.
It is further expected that the properties of connected speech will
make acoustic evaluation of the target words quite difficult, de-
spite the fact that they will be uttered in the same context for
the three testing sessions. We do expect that subjective evalua-
tions of these utterances by our panel of accent judges will be
possible, however; and this is the main reason for their collection.

2.5.2.4 Intra-session logic. As described above and detailed in
Appendix C, Ss are constrained by the software in certain ways as
they progress through a training session. This fine-grain control
of response contingencies shapes optimal speaking habits, and con-
strains S to pass from one word to the next only on error-free
completion of a previous utterance. At a grosser level, the instruc-
tions constrain S to budget her time during the session in other
ways. The first quick runthrough of the stack of LM cards is for
S's familiarization with the entire set, and to identify difficult

45

words. The constraint of a minimum of two successful STOREs for each word when moving through the stack ensures a minimum exposure of $\underline{S}$s to the material as they are trained.

2.5.3 Software Modifications

2.5.3.1 Miscellaneous. When any of the above changes are reflected in differences in the operation of the controlling program, software modifications are implied.

2.5.3.2 Additional behavioral counter. Just after the beginning of the current experiment, we realized that a rather important performance datum was not being recorded. The operations described in Section 2.3.2 preserve the number of times $\underline{S}$ presses the STORE button for each word in the training list, but fail to note the number of times $\underline{S}$ was successful in meeting the timing and volume criteria enabling her to hear the teacher's voice. It was a simple matter to add a counter for the number of times STORE was pressed and not followed by the word REPEAT on the CRT. The intra-word differential between the total and successful attempts should give an interesting index of motivational and performance variables.

2.6 THE CURRENT EXPERIMENT

On 22 June 1970, the revised second-language experiment was begun. All modifications discussed above are implemented and operating. There is one further change in the experimental design which deserves mention at this point. It involves the procedures outlined in Section 2.2.4.1: $\underline{S}$ selection. It was decided that the interview technique for selecting $\underline{S}$s was too prone to error from several sources, the strongest of which was the mimicry effect. We therefore determined to select $\underline{S}$s by screening them with the full

pretesting procedure. Accordingly, we invited all previously interviewed Ss back—including those previously rejected—and treated them all as if it were the pretest day. The history tapes from those sessions were dubbed from their scrambled, repetitious order into standard-order, single-utterance-per-word pretest tapes, which were used as the basis for S selection procedures.

The methods used after this point properly pertain to the next, final report for the project. This report will contain a description of all procedures used to specify Ss, accounts of training and the addition of new displays for other speech parameters, and a results and discussion section.

2.7   APPENDICES

2.7.1   Appendix A: Verbal Instructions Used in the Pilot Experiment

PART I -- SPEAKING SPANISH WORDS

At the start of the session, press BUTTON #9, wait for the "GO"
signal, and say "sisa." This will start the machine. Then, go
through the rest of the list of Spanish words, using BUTTON #9
and BUTTON #8 as described below.

List of Spanish Words
1. sisa
2. peso
3. padre
4. cosa
5. su

BUTTON #9.   Press this button when you are ready to speak a new
word on the list of Spanish words. The screen will go blank, and
then the "GO" signal will appear. Speak the new word when you see
this signal. Make sure you are speaking the right word. The num-
ber at the lower left of the box tells you which word on the list
the machine thinks you are speaking.

BUTTON #8.   Press this button when the machine says "repeat," to
indicate that there was something about your last word that it did
not like, or if you, yourself, feel that you could have said the
word better, or if you said the wrong word by mistake. This gives
you another chance to speak the same Spanish word. Speak the word
when you see the "GO" signal. You may press BUTTON #8 as many
times as you want, but the only thing the machine will remember
will be the last time you correct a word before going on to the
next one on the list of Spanish words. Make sure you are speaking

48

the right word by matching the number on the screen with the
number of the word in the list.

When you and the machine are satisfied with your version of "su,"
go to PART II. BUTTON #9 and BUTTON #8 are used only in Part I.

PART II -- LEARNING TO PRONOUNCE ENGLISH WORDS

At the start of Part II, press BUTTON #6, pick up the first teach-
ing card in the stack given to you at the beginning of the session
(it should be numbered #1), and put it through the card machine.
The number #1 will appear at the lower left corner of the box on
the screen, indicating that the machine expects you to be working
on teaching card #1. From here until the end of the session, you
may use any of the following buttons.

STORE. Press this button when you want to record your voice as
you imitate the word which you entered from the teaching card.
The screen will go blank, you will hear the teacher's voice speak
the word, the "GO" signal will appear, and you can then speak the
same word. (For feedback subjects:) The screen will then show you
the position of your tongue during the vowel part of the word.
The bright point shows where your tongue was at the beginning of
the vowel, and the string of other points shows where it went
after that. If the points pass through the target box in the same
way as they do in the sample picture shown on the teaching card,
the machine is telling you that the word you just spoke sounded
right. If the points do not pass through the target, or if they
do so in the wrong way, you must try to improve.

RECALL. Press this button to <u>listen</u> to both the teacher's voice
and your last imitation of it. When you press RECALL, the + at
the lower-right corner of the box will disappear, but the rest of
the screen will not change. You will hear both voices, one after
the other, and you will not have a chance to record your speech
during this time. The machine will respond to new demands only
when the + reappears at the lower-right corner of the box. (The
following two buttons will be described only to feedback subjects.)

BUTTON #1. Press this button to get a <u>continuous</u> picture of what
your tongue is doing, to help you try out different sounds quickly.
Concentrate on hitting the target for the particular word you are
working on, rather than making widely different sounds. This is
because the machine is still expecting you to speak the particular
vowel, and can do the best job on it. You may notice some small
differences in your ability to hit the target while the machine
is operating in this way. Therefore, please remember that we are
most interested in teaching you to pronounce whole words, as you
do when imitating the teacher's speech after pushing the STORE
button. So, use BUTTON #1 to help you get a rough idea of the
correct sounds, but do not spend too much time looking at the con-
tinuous picture of your tongue position.

The machine will not respond to your pushing the STORE or RECALL
buttons after BUTTON #1 is pushed.

BUTTON #0. Press this button to <u>return to normal</u> operations from
the continuous picture. STORE, RECALL, BUTTON #6, and BUTTON #7
will then operate normally.

BUTTON #6. Press this button when you are finished with one teach-
ing card and you want to begin working on the next one. Put the
card you have finished at the bottom of the stack, and pick up the
top one. When the "GO" signal appears on the screen, push the
card to start it into the machine. The machine will then know that
you wish to work on the next word. The (target box will move to
a new location within the larger box, and the) number at the lower
left of the box will increase by one from its value at the last
word you were working on. Check carefully to see that the number
on the screen and the number on the teaching card agree. If they
do not, see BUTTON #7.

BUTTON #7. Press this button to correct the situation when the
number on the screen and the number of your current teaching card
do not agree. This can happen if you put the wrong teaching card
into the machine, or if you put in the right one too late or other-
wise badly. Press BUTTON #6, wait for the "GO" signal, re-enter
the correct teaching card, and then press BUTTON #7 as many times
as are required to get the number on the screen and the number on
your card to agree.

BUTTON #1. If you have any questions during the session that you
cannot answer by referring to this outline, press this button, ask
your question into the microphone, and the person outside will
answer it for you.

2.7.2 Appendix B: Vowel-Display Algorithms

This appendix describes the final form of the vowel-display algorithms, as used in the ongoing formal evaluation of the English pronunciation teaching system. In summary, the vowel-display algorithms are used to estimate a two-dimensional trajectory of the tongue body during the voiced portion of single-syllable English words. This trajectory is displayed on a computer-controlled oscilloscope along with a small rectangle. The rectangle indicates a target articulation for the current word, as shown in Fig. B-1.

The vowel trajectory consists of a sequence of displayed points, the first point being more intense than the others to assist in identification of trajectory direction in time. Each point represents the approximate tongue position during the previous 10 msec.

The vertical position, or tongue height, is related to the frequency of the first formant, and can be estimated by the function:

$$\text{High}(nT) = [F1(nT)+F2(nT)+F3(nT)] - [F4(nT)+F5(nT)+F6(nT)]$$

where $F1(nT)$ is the output, in logarithmic units, of the first filter at time nT.

The horizontal position of a display point is related to the frequency of the second formant. Due to the wide range of variation of the second formant in natural speech, and due to frequency range overlap with the first and third formants, it has been found that several different horizontal position functions are needed to estimate the position of the tongue body in the front-back

52
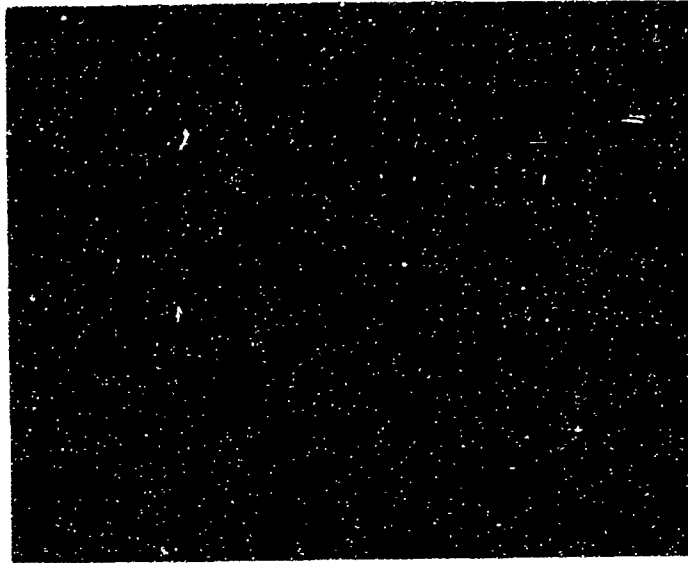
Fig. B-1. Vowel display, showing trajectory and target
rectangle for the vowel /ɛ/ in the word "bet." Numeral
at lower left indicates word number in the list; + at
lower right is the ready signal. If utterance is unac-
ceptable, REPEAT appears between numeral and +, and
trajectory does not appear.

In Part I, large rectangle is always empty. Expected
Spanish word appears in place of numeral. OK appears
whenever REPEAT does not.

dimension. The specific front-back function to be used at any
one time is selected according to the vowel that is currently
undergoing training (Table B-1, Column 2):

Function
Number

$$\text{FRONT}(nT) = \begin{cases} (1) & [\Sigma F4 \text{ to } F10] - [\Sigma F1 \text{ to } F3] - [\Sigma F11 \text{ to } F14] \\ (2) & [\Sigma F5 \text{ to } F7] \quad - [\Sigma F8 \text{ to } F10] + 256 \\ (3) & 1/2 \, [\Sigma F1 \text{ to } F4] \quad - 1/2 \, [\Sigma F5 \text{ to } F8] + 960 \end{cases}$$

The trajectory is displayed only during the voiced portion of the
word, and the trajectory is further restricted to the portion of
the vowel nucleus that is minimally affected by coarticulation
with adjacent consonants. To accomplish these goals, the trajectory
is delimited in time to begin at time $n_b T$ and to end at time $n_e T$
by the algorithm described below and illustrated in Fig. B-2.

$$\text{Let LOUD}(nT) = F2(nT) + \log \left[\sum_{m=1}^{19} \log^{-1}(Fm(nT)) \right]$$

where $Fm(nT)$ is the output of the mth filter at time nT.

$$\text{Let MAXLOUD}(n_m T) = \text{MAX}_n [\text{LOUD}(nT)]$$

Then the beginning of the trajectory is found by working backward
from time $n_m T$ until $\text{LOUD}(nT)$ is less than $\text{MAXLOUD}(n_m T)$ minus 24.
This time marks the approximate beginning of voicing. To remove
part of the influence of the initial consonant, $n_b T$ is set equal
to this time plus $3T$.

A similar algorithm defines the last point in the trajectory, $n_e T$,
by looking forward from $n_m T$ until $\text{LOUD}(nT)$ is less than $\text{MAXLOUD}(n_m T)$
minus 24. The end of the trajectory is set equal to this time

Table B-1. Display Parameters for Each Vowel

	Vowel	Front-Back Function #	Front-Back Box Position	High-Low Box Position	Horizontal Box Size
1.	i	1	i_s	i_s	256
2.	I	1	$(i_s+e_s)/2+256$	e_s+256	512
3.	e	1	e_s	e_s	256
4.	ε	1	e_s+512	$(e_s+a_s)/2$	512
5.	æ	1	a_s-896	a_s+256	768
6.	a	2	a_s	a_s	256
7.	ɔ	3	a_s+256	a_s+256	256
8.	o	3	o_s	o_s	256
9.	ʊ	3	o_s-128	o_s+256	512
10.	u	3	u_s	u_s	256
11.	ʌ	2	a_s-256	a_s+256	256
12.	ɚ	1	a_s-384	$(o_s+u_s)/2+128$	512
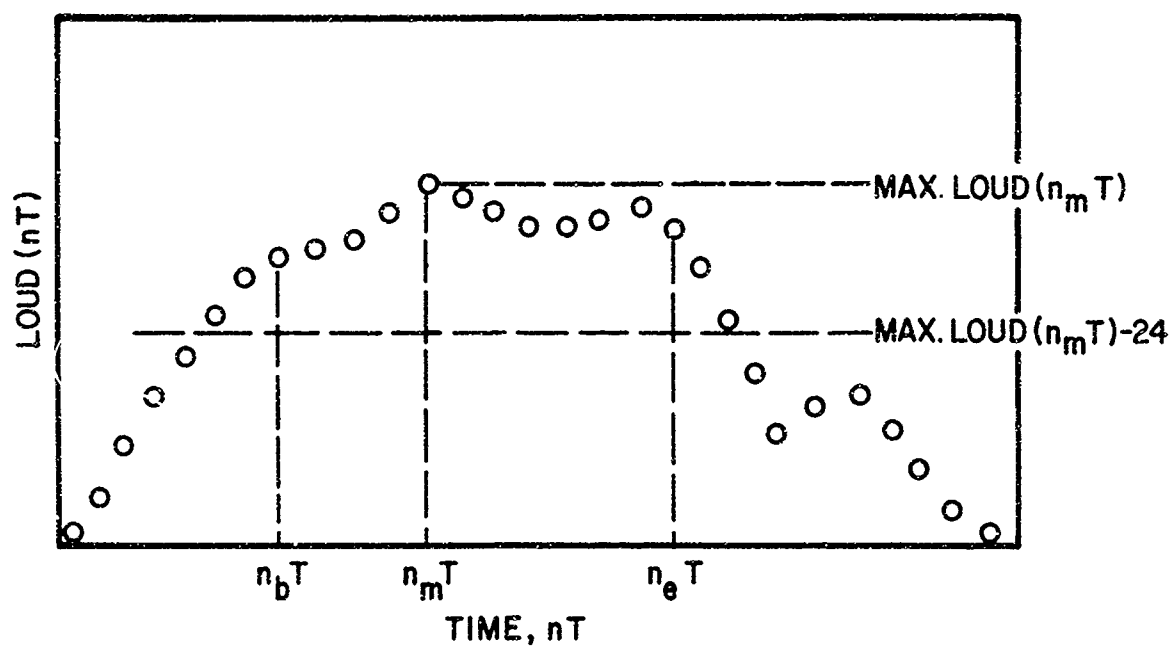
Fig. B-2. The time interval over which the vowel trajectory is displayed is from sample $n_b T$ through sample $n_e T$.

minus 3T.   A test is made to insure that c_r ̃ ̇ ̇ ̇
or the utterance is rejected.

A target rectangle is positioned on the display ̇ ̇ ̇ ̇
centered at the horizontal and vertical coordinates x_r, ̇
has a size (horizontal and vertical box lengths) x_s, ̇ ̇
coordinates of the center of the rectangle are determine ̇ ̇
display position of the mid point in time of the Spanish ̇ ̇ ̇
/i_s, e_s, a_s, o_s, u_s/ and a set of offset constants that wer ̇ ̇ -
articulation with adjacent consonants.   Table B-1 indicates the
front-back and high-low box positions of the rectangle for each
vowel as a function of the positions of Spanish vowels.   Offset
constants are not given in this report.

The vertical size of the rectangles, y_s, is 256, but the horizontal
size depends on the vowel because some free variation seems per-
missible in horizontal position for some vowels.   The horizontal
rectangle size is given in Table B-1, Column 5.   The total size of
the vowel display screen is <3072, 1892>.

57

2.7.3 Appendix C: English-Language Version of Instructions

The foll wing pages contain the instructions given to each $\underline{S}$ on
the pretest day. At a predetermined point, indicated by an (*)
sign, $\underline{E}$ would ask $\underline{S}$ to stop reading, and would give a brief demon-
stration of the operation of the machine. At the point marked
(**), $\underline{E}$ demonstrated the recording technique, using the dummy
word TEST, recorded on a preliminary LM card. At the point marked
(***), $\underline{S}$ began execution of Part II by recording the dummy word
SAMPLE, recorded on a preliminary LM card. Then, $\underline{S}$ proceeded
through the 57 regular LM cards.

INTRODUCTION TO THE TEACHING MACHINE

As you know, we have a new teaching machine whose purpose is to improve the English pronunciation of Spanish-speaking people. We want to introduce you to the various parts of this machine. You will be able to learn more quickly if you understand how the teaching machine's parts work with each other and with you. The equipment may seem complicated as you first read about it, but you will find that after a few minutes of experience, you will be using the teaching machine almost automatically, improving your English pronunciation and having fun too! If you have any questions as you read this, we will be glad to answer them at any time.

<div align="center">* * * * * * * * * *</div>

Our teaching machine occupies two rooms: one for the student, and one for some extra equipment and the Monitor, who is there to make sure the equipment is working OK. In the Monitor's room there is a computer that controls all of the rest of the equipment in response to your commands from the student's room, and there is also a tape recorder which plays its sounds into the student's room. This recorder has, instead of a long spool of tape, just a small loop of tape which goes around. Each time you start it, it goes around once; and that takes about 5 seconds. You can record your own voice on the tape, and you can also listen to the recorded voice of a teacher on that tape. You can listen or record with the tape as many times as you want, as you improve your pronunciation.

Inside the student's room, there are several pieces of equipment which you will use as you learn.

1. BUTTON BOX. Whenever you wish to do anything with the
teaching machine, you must ask the computer to help you. Since
our computer is not too smart, it will respond only to a small
number of instructions, and you have to translate your instruc-
tions into button-pushes so that it can understand you. You can
start each activity by pressing one of the 12 buttons on the
button-box. Later instruction sheets will give you further de-
tails about which button goes with which activity.

It is important that you always press the buttons as quietly as
possible. When you have decided whicn button you want to push,
put your fingertip on the button lightly without pressure. Then,
press down softly and release quietly. It is especially impor-
tant that you release the button quietly. You don't have to
press the button with great force; just make it touch bottom.
You also don't need to release the button hastily. Usually, just
"letting up" on your finger pressure will allow the spring under
the button to push up your finger quietly. This method is impor-
tant, but don't let it worry you too much; it will soon become
automatic, and you won't even have to think about it!

2. DISPLAY SCREEN. The computer draws things on this screen to
give you information about that's going on during the lesson.
It's like a TV screen, but the "pictures" you see are much sim-
pler , and you can change them by what you do while you learn.
Later instructions will tell you what each of the pictures mean
and what you can do to change them.

3. MICROPHONE. This is, of course, what you speak into. When-
ever you wish to record a word, you must instruct the computer
to turn on the microphone. You do this by quietly pressing one

of the buttons on the button-box. Later instructions will tell
you which buttons to use. After you press the right button, the
computer tells you that the microphone is ready by removing what-
ever picture is on the screen and replacing it with a picture
that looks like this: →] This is your signal to speak. It will
stay on for only about 2 seconds, and so you should speak your
word as soon as you see the →] signal on the screen.

4. LOUDNESS INDICATOR. When you speak into the microphone, your
voice must not be too loud or too soft, or the computer won't be
able to "understand" what you've said. The loudness indicator
moves in response to your voice when the microphone is on; the
louder you speak, the further it moves. Watch the meter while
you speak.

5. TEACHING CARDS. Each time you come, you will study the pro-
nunciation of a certain set of English words. You will have help
in doing this, since we have recorded a teacher's voice speaking
the words you are to work on, and you can hear the teacher's
voice whenever you wish. Before you begin each day's work, you
will be given a stack of cards, each with a number and a word
typed at the top right corner, and each with a piece of magnetic
tape running across the bottom. The teacher's voice is recorded
on the tape, and you can hear it by using the card-reading
machine.

6. CARD-READING MACHINE. The purpose of this machine is to
transfer the recording of the teacher's voice onto the tape loop
outside so that you can hear it. Later instructions will tell
you how to use this machine.

61

7. LOUDSPEAKER. Of course, this is where you hear the recordings of your voice and of the teacher's voice. Occasionally, if you are having difficulties, the Monitor will interrupt the session and speak to you over the loudspeaker too. You can answer him through the microphone. When the problem is solved, the Monitor will turn off the loudspeaker and give the control of the machine back to you.

<p align="center">* * * * * * * * * *</p>

Please ask any questions about these instructions, and we will be glad to answer them.

INTRODUCTION TO TODAY'S SESSION

Today's session will be different from the usual one. We have a large number of English words which we would like you to speak for us. We will record your voice, and wè will use this recording to measure the progress you make through the use of this machine. The monitor will stay in the student room today, and he will do most of the complicated things. All you have to do is speak the words into the microphone.

Today's session will have three parts: Part I, in which you will speak a short list of Spanish words; Part II, in which you will speak some English words; and Part III, in which you will read some English sentences.

Part I will be done in exactly the same way as it will be done in all future learning sessions. After you complete Part I, you will read more about Part II and Part III.

PART I: SPEAKING SPANISH WORDS

The purpose of this part is to introduce your voice to the mac-
hine. Since every person's voice is different, the machine has
to know what yours is like if it is going to be able to improve
your pronunciation. We want you to speak some Spanish words now,
since we know you can pronounce them correctly. It is very im-
portant that you speak in a normal manner in Part I, since we
must measure any improvement in your English against these
Spanish words.

Here is a list of the five Spanish words you will record in Part
I. You will record them twice: once for practice, and then
once again. The order in which the teaching machine expects you
to record them is:

SISA   PESO   PADRE   COSA   SU

Here is a series of steps which you should follow to complete
Part I. If you read and follow them carefully, the whole thing
should take just a couple of minutes.

STEP 1. You will notice that there is a + in the center of the
screen. This means that the machine expects you to start at the
beginning of the list by recording the word SISA. Go on to Step
2.

STEP 2. Record the correct Spanish word. Here is how: Using a
light and quiet movement, press BUTTON 9. This removes whatever
was on the screen and replaces it with the →] signal, indicating
that the microphone is on. You then have a few seconds in which

to speak the Spanish word. Watch the Loudness indicator while
you speak.   (*)

When the microphone is turned off, the →] signal disappears and
is replaced with a more complicated picture. At the lower left
of the large rectangle, the computer tells you what Spanish word
it expected you to say. At the center, it says OK or REPEAT;
and at the lower right, a + will appear to indicate that you may
proceed.

Now you should take the actions indicated below.

      A. If the screen says REPEAT: You must go im-
          mediately to STEP 3.

      B. If the screen says OK: Continue to question
          C.

      C. Did you speak the word written in the lower
          left of the screen?

          1. Yes, I did: Continue to question D.
          2. No, I didn't: You must go immediately
             to STEP 3.

      D. When you spoke the Spanish word, was it your
          normal pronunciation of that word, and did
          your voice sound OK to you?

          1. Yes, my voice was normal: Go to STEP 4.
          2. No, there was something wrong: Go to
             STEP 3.

65

STEP 3. You enter this step because there was something wrong with the way you recorded a Spanish word. You want to get another chance to speak the same word, so you want the teaching machine to turn on the microphone while still expecting you to speak the old word. Here is how: Using a light and quiet movement, press BUTTON 8. This removes whatever is on the screen and replaces it with the →] signal, indicating the microphone is on. Watching the loudness meter as you speak, say the old Spanish word into the microphone.

Now, you should take the actions indicated below.

A. If the screen says REPEAT: You must go back to the beginning of STEP 3.

B. If the screen says OK: Continue to question C.

C. Did you speak the word written at the lower left of the screen?

1. Yes, I did: Continue to Question D.
2. No, I didn't: Go back to the beginning of STEP 3.

D. When you spoke the Spanish word, was it your normal pronunciation of that word, and did your voice sound OK to you?

1. Yes, my voice was normal: Go to STEP 4.
2. No, there was something wrong: Go back to the beginning of STEP 3.

STEP 4. When you arrive at this step, it means you have just
successfully recorded a Spanish word. Both you and the teaching
machine liked the way it sounded. Now, you should take the ac-
tions indicated below.

      A. Have you just finished any of the following
          Spanish words: SISA, PESO, PADRE, or COSA?

          1. Yes, I just finished one of these words:
              Then you are ready to start working on
              the next word on the list. Go back to
              STEP 2 and work on the new Spanish word.
          2. No, I have just finished the word SU:
              What do I do now?

Remember that the plan in Part I is for you to record the list
of five Spanish words two times.

      A. If you have finished with SU and this is
          your first time through the list of five
          Spanish words, press BUTTON 9 just once,
          and do not say anything. This erases
          the screen and puts a + in its center.
          Go back to STEP 1.

      B. If you have finished with SU and this is
          your second time through the list of five
          Spanish words, congratulations! You have
          just completed Part I, and you can go on
          to the rest of today's activities.

BUTTON 8 and BUTTON 9 are not used again today. They are only
used in Part I.

WHAT DOES IT MEAN WHEN THE SCREEN SAYS "REPEAT"?

You have pressed a button which was supposed to turn on the micro-
phone and allow you to speak a word to the teaching machine. The
→] signal appeared on the screen, and now the word REPEAT is writ-
ten at the bottom of the rectangle on the screen. What does it
mean?

It does not mean that you have pronounced the word incorrectly.
The machine is not that smart! It does mean that the computer
did not think that what it heard was a word. There are several
things that can cause a REPEAT.

> 1. You did not say anything while the microphone
> was on. Once the →] signal appears on the screen,
> you have only about two seconds in which to speak
> the word. If you wait too long, the microphone
> will turn off too early. Make sure you speak as
> soon as the →] signal appears on the screen. !

> 2. You started to speak the word too early and
> were in the middle of saying it when the →] signal
> appeared on the screen. Remember to wait for the
> →] signal before beginning to speak the word.

> 3. There was a short noise while the microphone
> was on, before you could speak. If the noise is
> loud enough, the machine thinks that is the word,
> and it turns off the microphone. It is very im-
> portant that the only sound after the →] signal
> appears should be your voice speaking the word.
> That is why you must press the buttons as
> quietly as you can.

4. Your voice was too soft while you spoke the word.
Are you sitting with your mouth more than 12 inches
from the microphone? Watch the loudness indicator as
you speak, and make sure that your voice makes the
needle pass above the lower mark.

5. Your voice was too loud while you spoke the word.
Are you sitting too close to the microphone? Watch
the loudness indicator as you speak, and make sure
that your voice does not make the needle go past the
upper mark.

PART II: SPEAKING ENGLISH WORDS

Now we are ready for you to speak a list of several English words.
It will be very simple for you, since all you must do is press
one button and speak each English word. The monitor will do
everything else. We will use the following procedure for all of
the words.

Step 1. The monitor takes a new teaching card, presses BUTTON 6,
waits for the →] signal to appear on the screen and puts the card
into the card-reading machine. You will not hear the recording
of the teacher's voice yet. The word you will speak is printed
at the top right corner of the teaching card.

Step 2. After the new teaching card is entered, there will be
some slowly changing numbers at the lower right corner of the
screen. The numbers will get smaller, and they are finally
replaced with a +. This means that the machine is now ready for
you to speak the English word printed on the teaching card.

Step 3. Before you speak, you must tell the machine to turn on
the microphone. Using a light and quiet movement, press the but-
ton marked STORE. This will erase the screen and put the →]
signal on it, indicating that you may now speak. Do not worry
about mispronouncing the word; you will get a second chance very
soon. Watching the loudness meter, speak the English word written
on the teaching card. Remember, you only have a few seconds in
which to speak the word after you press the STORE button, so speak
it as soon as you see the →] signal appear on the screen.

<div align="right">(**)</div>

Step 4. Now, one of two things can happen:

A. If the screen says REPEAT: There was something wrong with the way you spoke the word. You won't hear the teacher speaking the word until you say it, and the screen does not say REPEAT. Wait for the + to appear at the lower right of the screen, and then go back to the beginning of Step 3.

B. If the screen does not say REPEAT: The machine is satisfied with what you said. You will now hear the teacher's voice saying the English word. Listen carefully to his pronunciation, because you will soon get another chance to speak the word. After the teacher is finished speaking, wait for the + to reappear at the lower right of the screen, and then continue to Step 5.

Step 5. You have now spoken the word at least once, and have heard the teacher say it once. You can now say it again. Using a light and quiet movement, press the STORE button and use the same procedure as in Step 3 to speak the word once again.

Step 6. Now, one of three things can happen:

A. If the screen says REPEAT: Wait for the + to re-appear at the lower right of the screen, and then go back to Step 5.

71

B. If you feel you could say the English word better,
that you were not concentrating, or that your voice
did not sound "right" to you as you spoke: Go back
to Step 5.

C. If you and the monitor and the machine were
satisfied, we can go on to the next English word
on the list. Go back to Step 1.

(***)

PART III: READING ENGLISH SENTENCES

We would like to record your voice as you read some English sen-
tences. We know that reading English is not easy if you are not
sure of how to pronounce written English, so do as well as you
can and do not worry about making mistakes.

Before you begin reading aloud, the monitor will give you a paper
with the English sentences you are to read. He will read it aloud,
while you follow along, reading silently. When he turns on the
microphone, you will then read the same sentences at a normal con-
versational speed and loudness.

The following page appeared at the front of the instructions given
to experimental and control Ss on the training days. The next few
pages of the instructions are not shown here, since they are iden-
tical to those given on the previous pretest session: the in-
structions for Part I, and the section entitled "WHAT DOES IT MEAN
WHEN THE SCREEN SAYS "REPEAT?". The next section in the instruc-
tions is "PART II: LEARNING TO PRONOUNCE ENGLISH WORDS," and it
differed between experimental and control Ss. They are identical
up to Section D, entitled HOW THE TEACHING MACHINE HELPS YOU IMPROVE
YOUR PRONUNCIATION. Following the conclusion of the instructions
for Part II, you will find the one-page summary of the instructions
and functions of the buttons. The following pages contain the in-
structions given to control Ss, from Section D until the conclusion
of the instructions for Part II. This is followed by the control
Ss' one-page summary. The next page is self-explanatory.

The relevant package of instructions is always present in the room
when S is running. In addition, S was given the package of in-
structions for reference and study at home. The covering letter
attached to the instructions is the last item in this appendix.

INTRODUCTION TO TODAY'S SESSION

Today we will begin the normal operation of the teaching machine
There are two parts to this session: Part I, where you will
speak the same list of Spanish words as you did on your first
day, and in the same way; and Part II, where you begin to use
the teaching machine to improve your English pronunciation. We
will give you complete instruction sheets for both Parts. You
have already seen the instructions for Part I, and so that should
be easy.

PART II: LEARNING TO PRONOUNCE ENGLISH WORDS

You are now ready to begin using the teaching machine to improve
your pronunciation of English words. You have been given a
stack of numbered teaching cards which you can use for the rest
of today's lesson.

For the most part, you are now free to work on the English words
at your own pace. Here is a description of how to control the
teaching machine and of the general rules for Part II, which you
should understand.

A. HOW TO BEGIN WORK ON A NEW ENGLISH WORD:

The first step in working on a new English word is to tell the
computer you are finished with the previous activity and that
you want to place a recording of the Teacher's voice onto the
tape loop where you can listen to it. This is done in the fol-
lowing way:

STEP 1. Press BUTTON 6. This begins the process and removes
whatever is on the screen. If this is your first teaching card
in the stack, skip to STEP 3.

STEP 2. Take the previous teaching card out of the slot of the
machine and place it face down on the stack of used cards.

STEP 3. Put the next teaching card in the slot of the machine
and slide it over to the left until its left edge is near the
little triangle.

STEP 4. A few seconds after you push BUTTON 6, the →] signal should appear on the previously blank screen. This doesn't mean you should speak into the microphone; it means the computer is ready for you to start the teaching card. Wait until the →] signal appears on the screen before going to STEP 5.

STEP 5. Now, give the card a little push to the left, and the machine will pull it the rest of the way. When the card stops it will remain at the left edge of the machine. Leave it there so that you can read what the word is.

STEP 6. If the machine was not satisfied with something as you did STEP 5, it will say REPEAT ON The screen. You must go back to STEP 1, while of course leaving out STEP 2.

STEP 7. Look carefully at the word number printed above the English word on the teaching card. Now look carefully at the word number at the lower left corner of the screen. It is very important that these numbers always agree, since this is the only way the computer knows what word you're working on. Usually, if the cards are kept in order and you have no trouble entering them with the card-reading machine, the numbers will remain in agreement.

Do they agree now?

A. Yes, they are the same number: Go to STEP 8.

B. No, they are different: Here is how to make them agree. Each time you push BUTTON 7, the word number on the screen gets smaller by 1. If you push it twice when the original number was

77

"10," it will change in this way: "9" - "8." If you push it
three times when the original number was "2," it will change
like this: "1" - "0" - "12." Therefore, watch the screen as
you push BUTTON 7 as many times as are necessary to make the
two word numbers agree.

STEP 8. You are now ready to begin working on the pronunciation
of this English word. You have not heard the Teacher's voice
saying it yet, but you have transferred the recording of his
voice from the teaching card to the tape loop outside. You can
hear it played through the loudspeaker whenever you want, as you
study how to pronounce this word. But before you begin working
on the first word, please read the rest of these instructions.
The section titled GENERAL LEARNING PROCEDURE will give you some
rules and suggestions for what you should do.

B. HOW TO RECORD YOUR VOICE

When you want to put a recording of your voice on the tape loop,
use the STORE button. Remember: press it quietly, wait for the
→] signal, and watch the loudness indicator as you carefully
speak the English word.

If the teaching machine does not say REPEAT, you will hear the
teacher's voice speaking the English word after you. If you hear
nothing and the screen says REPEAT, you must repeat this step;
no other buttons will function.

Listen carefully to the teacher's voice as he speaks the English
word. Can you hear any differences between the way he speaks
and the way you have just spoken?

78

C. HOW TO LISTEN TO THE RECORDINGS

One of the best ways you have of improving your pronunciation is
listening to both voices speaking the same word, in quick suc-
cession. You can do this with the RECALL button. When you press
the RECALL button, the + at the lower right of the screen dis-
appears, and the teaching machine will play the tape loop through
the loudspeaker for you to hear. The microphone will _not_ be
turned on, since you can only listen with the RECALL button. You
will hear the last recording of your voice which you made with
the STORE button, and then you will hear the teacher's voice
speaking the English word. Can you hear any differences between
the way you speak and the way he speaks?

D. HOW THE TEACHING MACHINE HELPS YOU IMPROVE YOUR PRONUNCIATION

As you probably know, English has more vowels than Spanish does.
Some of them are similar to Spanish vowels, and some are quite
new and different. Most Spanish-speaking people have some degree
of difficulty in pronouncing the English _vowels_. There are, of
course, several _other_ kinds of difficulties which you may have in
speaking English. In a few weeks, we will explain how to use the
teaching machine to help you with _those_ problems. For the next
several sessions, as you use the STORE and RECALL buttons in
gradually making your pronunciation identical to the teacher's,
the screen will give you information which you can use in im-
proving your pronunciation of English vowels.

Each of the 12 Teaching Cards contains a one-syllable English
word. We do not think that you will have too much difficulty in
pronouncing the consonants in these words, but we think you might

79

find some of the vowels hard to pronounce correctly. Each of the 12 English words contains a different vowel. To pronounce all of these vowels correctly, your lips, teeth, and tongue must all be in the right places at the right times. This sounds like a difficult task to accomplish, since we usually speak without thinking about it. But in order to improve your English vowels, you must learn to change your speaking habits by really trying to do new things with your mouth.

Fortunately, your task is made simpler by the nature of the English vowels. In most of them, the position of the lips and teeth is not nearly as important as is the position of the tongue in the mouth. Different tongue positions produce different vowel sounds. When the tongue is high and forward in the mouth, a vowel like the I in SISA is produced. When the tongue is low and back in the mouth, a vowel like a U in SU is produced.

Some English vowels are difficult to pronounce because your Spanish-speaking training has never required you to put your tongue in certain regions of your mouth. You can easily produce all Spanish vowels without thinking about it; but when you speak English, you use something like the Spanish vowel positions; and the result of this substitution is an accent. If you could learn new ways to move your tongue, you could greatly improve your Spanish accent. Unfortunately, this kind of new learning is hard for most people, since usually we speak without thinking about all of the things we have to do in pronouncing words. But you have the teaching machine to guide you in this learning. It can tell you how to change the position of your tongue in order to improve your vowels.

80

Each time you speak a word into the microphone, the teaching
machine will look for the vowel part of the word. When it hears
you speaking a vowel, it starts figuring out where your tongue
is in your mouth. It determines this position every 1/100th of
a second until you are through speaking the vowel. When you are
finished with the word and the microphone is turned off, it
shows you on the screen where your tongue was while you spoke
the word.

The large rectangle on the screen is a simple representation of
a left side view of the mouth—oriented like the rectangle in
the picture on the front of the loudspeaker. The teaching mac-
hine shows you where your tongue was by putting a series of
points in the rectangle. The _bright_ point is the position of
your tongue at the _start_ of the vowel and each successive point
is its position on each successive 1/100th of a second until the
end of the vowel. If the points are clustered near the top left
corner, this means that your tongue was high and forward in your
mouth. Therefore, you can use this picture to get information
about _where_ _your_ _tongue_ _is_ _as_ _you_ _speak_ _vowels_. Now: How do
you know how to change your pronunciation to make it _better_, and
how do you know when you are _right_?

You will notice that inside the large rectangle, in addition to
the string of points, there is a smaller rectangle. This is
called a target. There are 12 different targets, one for each
English word. Each of them indicates the region of your mouth
where your tongue should be for correct pronunciation of each
English vowel.

81
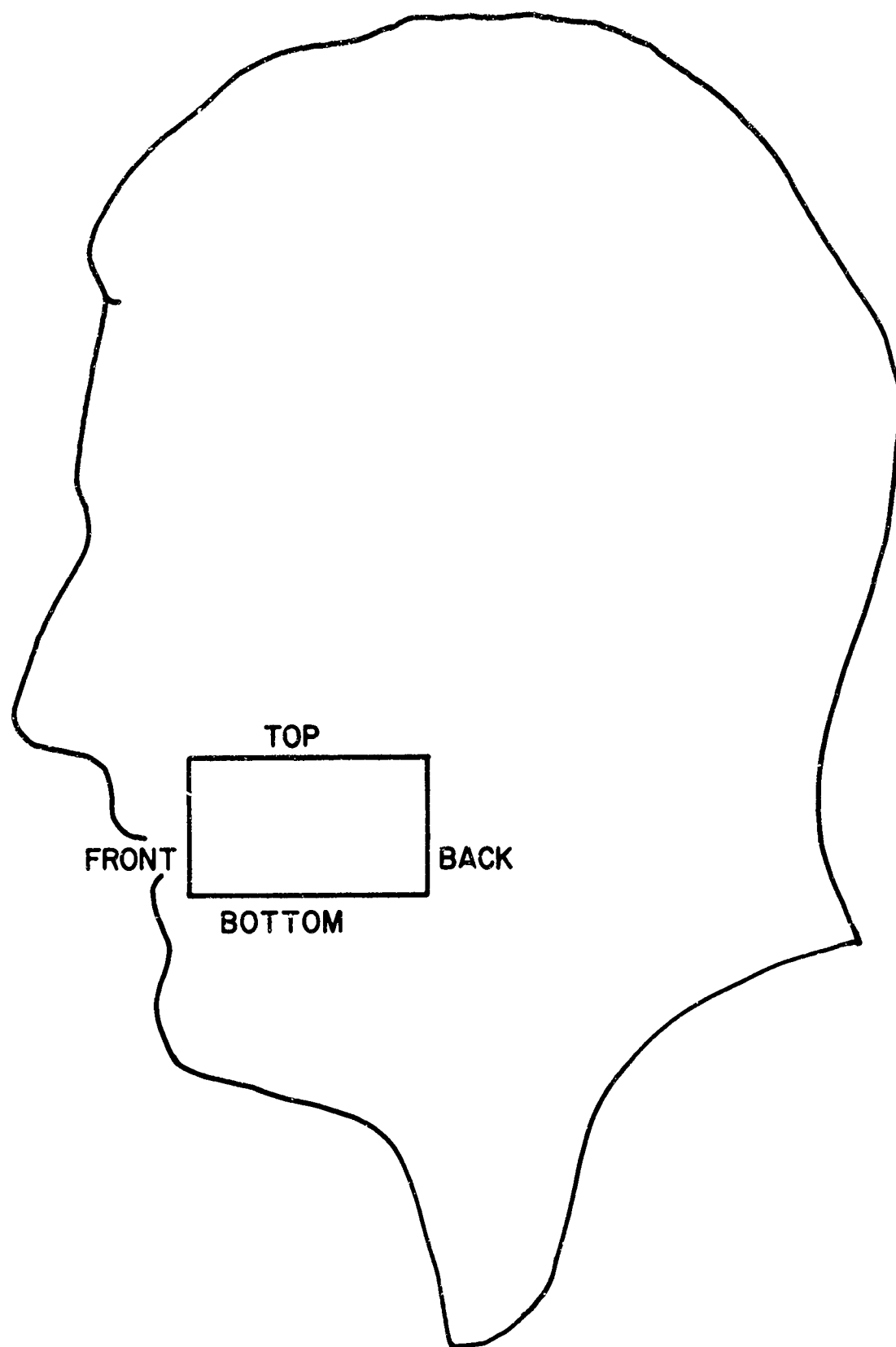
Fig. C-1. Diagram placed before experimental $\underline{S}$s
during training sessions.

If the trace of points does not touch the target at all, the
teaching machine is telling you that you are pronouncing the
vowel incorrectly and that you must try to improve. You can use
the relative positions of the trace and the target to tell your-
self how to change your tongue position for your next try. If
the trace is just above the target, your tongue is too high. If
the trace is to the right of the target, your tongue is too far
back. The next time you speak the word, try to move your tongue
to the position indicated by the target.

It is easy to see when you are wrong—the tongue trace does not
touch the target. It is a little more difficult to see when you
are really correct, since it involves some judgment on your part.
While it is very good when your trace hits the target, it is even
better if you can touch the very center of the target with some
part of your trace. We must tell you that there will be targets
which you can just barely touch even with prolonged learning,
and you will never be able to touch their centers. But you
should try to do this every time, when possible. Please notice
that we did not say that the entire trace should be within the
target; only that it is good if you can get your trace to touch
the center of the target.

You should also make sure that you can hit the target consistent-
ly. It is not enough that you managed to produce a perfect
trace once. Can you repeat the performance whenever you want?

Here is another very important thing to remember. Whenever you
are using this system, do not depend entirely on the tongue-
position pictures. Remember your ears! Your pronunciation of
the words is supposed to sound identical to the teacher's voice,

83

and the pictures are only to help you in learning the correct vowel sounds. If your trace hits the target well, that does not mean that all of your pronunciation is perfect. Listen to the whole word and try to get every part of it to sound like the teacher's voice.

E. USE OF THE CONTINUOUS-PICTURE BUTTON

There will be times when you are just interested in getting a quick look at the tongue trace as you speak into the microphone, and when you don't want to spend all of the time that is needed when you use the STORE button. You may want to speak the word several different ways, or you may just want to try out some slightly different vowel sounds or tongue positions. This is made possible through BUTTON 1.

When you press BUTTON 1, the + at the lower right of the screen disappears, and the microphone is turned on. Any sound you make is now picked up by the teaching machine; and when it hears a vowel sound, it will put a series of tongue-position points on the screen right while you are talking. You can now try out several different words or vowels in quick succession. Here are some suggestions on how to use BUTTON 1.

You are working on improving your pronunciation of some English word. The target for the vowel sound of that word is shown on the screen. Speak the whole word into the microphone and watch the screen. While you are speaking the vowel part, try tongue positions that are different from your usual one. Try to move the trace closer to the target each time you speak the word. If this does not work, you may be working with a vowel in which

the position of your lips or teeth makes a difference. Speak the word some more, and try to change the shape of your lips or teeth as you speak the vowel. Does this move the trace into the target?

Another way you can use BUTTON 1 is to make a continuous series of speech noises in your throat and speak just the vowel part of the word. Try the little experiments mentioned above. Can you make a vowel sound that puts the trace in the target? If you find that you can, then go back to speaking the whole word and put the correct vowel sound in the middle of it.

As you use BUTTON 1 and try these new sounds, remember to work only on getting the vowel trace to hit the target that is now on the screen. Try vowel sounds that are roughly similar to the one you are working on. You can, if you want, try other English words that have the same vowel; but you should work mostly on the current English word on the teaching card. If the vowel is EE, don't try to speak OO, since the trace of that vowel will not be shown correctly on the screen. But if the English word is BEET, you might try different EE sounds, and maybe the word FEET or something like that.

You may find that you can not hit the target while using BUTTON 1 and that you can while using the regular STORE procedure. Or, the difference may be reversed. This is because there are some small differences between the two buttons. BUTTON 1 is for you to get a rough idea of how you should change your pronunciation to help you hit the target when you speak the word in STORE. We are more interested in your being able to hit the target as you speak the word with the STORE button, so use BUTTON 1 only when it can really help you.

85

When you want to go on to another activity, you must instruct
the computer to turn off the continuous picture and get ready
for a new STORE or RECALL command. Remember that the + at the
lower right of the screen must be present for these buttons to
work and that pressing BUTTON 1 removed the +. To return to
normal operation, press BUTTON 0, which will replace the + and
allow you to go on to your next command. Remember: once you
have pressed BUTTON 1, you must press BUTTON 0 before the machine
will listen to any further commands.

F. IN CASE OF TROUBLE

The monitor will sit outside and keep watch over the machine to
make sure that it is working normally. If there is trouble of
some kind and he wants to talk to you, he can speak to you over
the loudspeaker. This will interrupt the picture on the screen.
You must wait until he is through speaking to answer him. He
will tell you when the problem is fixed and will then let you
take control of the machine again.

Please do not hesitate to ask questions about <u>anything</u> you feel
unsure about!

G. GENERAL LEARNING PROCEDURE

Now you know how to use the teaching machine to help you improve
your pronunciation of each of the English words. Before you be-
gin, we still need to tell you the general rules for Part II.

You will find that if the screen says REPEAT, you will not be
able to start a new English word with BUTTON 6, because the

86

machine will not respond. You must press STORE and speak the
old word one more time to get rid of the REPEAT, and then you
can continue with BUTTON 6.

You may know already that when you finish with the 12th teaching
card, you can go right back to the first card as your next
English word to work on. You can, therefore, go through the
stack of 12 words several times during each day's session. You
can work at your own pace for most of the time.

We would like you to observe the following rules as you go
through the session. When you begin PART II, run through the 12
words rather quickly. Each time you enter a new teaching card,
speak the word no more than three times with the STORE button,
and use the RECALL button no more than three times. Use BUTTON
1, if you wish, but not for more than about a minute. If you
have difficulty with a particular word, note down the problem,
if you want, on the note-paper provided. You will have the time
to return to work on that word later in the session.

Once you have finished this quick run through the words, you can
go back to word 1, press BUTTON 6, and continue normally. Make
sure that the cards are in order and that the word numbers on
the screen and your cards agree. You can now spend as much time
as you want on each word in the stack. The only thing we re-
quest is that you STORE each word a minimum of two times before
going on to the next word in the stack. Make any notes you wish
to help you as you learn. You can go through the pile of words
as many times as you want during the session.

If there is an English word that the teaching machine does not seem to be able to help you pronounce correctly, no matter how many times you try it, make sure to tell the Monitor about it. The machine is not perfect yet, and there may be something wrong with it that we can correct before your next session.

Thanks for reading all these instructions! Please feel free to ask any questions you wish at any time. We will leave these instructions in the room with you as you work, so that you can refer to them whenever you want.

Enjoy yourself!

PART I: SPEAKING SPANISH WORDS

SISA   PESO   PADRE   COSA   SU

SPEAK THIS LIST TWICE, IN YOUR NORMAL SPEAKING VOICE.

MAKE SURE YOU ARE SATISFIED WITH HOW YOUR VOICE SOUNDS AS YOU

SPEAK.

BUTTON 9: TO BEGIN A NEW SPANISH WORD.

BUTTON 8: TO CORRECT AN OLD SPANISH WORD.

WHEN YOU FINISH THE FIRST RUN THROUGH THE LIST, PRESS BUTTON 9

ONCE, AND BEGIN AGAIN.

* * * * *

PART II: IMPROVING YOUR PRONUNCIATION OF ENGLISH WORDS

BUTTON 6: TO ENTER A NEW TEACHING CARD.

BUTTON 7: TO CORRECT DIFFERENCES BETWEEN WORD NUMBER ON SCREEN

AND ON CARD.

"STORE" BUTTON: TO RECORD YOUR VOICE AND THEN HEAR THE TEACHER.

"RECALL" BUTTON: TO LISTEN TO YOUR LAST RECORDING AND THEN TO

THE TEACHER.

BUTTON 1: TO BEGIN CONTINUOUS-PICTURE OPERATION.

BUTTON 0: TO RETURN TO NORMAL OPERATION FOLLOWING CONTINUOUS-

PICTURE.

ON YOUR FIRST RUN THROUGH THE STACK OF TEACHING CARDS, "STORE"

AND "RECALL" EACH WORD NO MORE THAN THREE TIMES. DO NOT USE

BUTTON 1 MORE THAN ABOUT A MINUTE. WHEN YOU GET BACK TO WORD 1,

YOU CAN SPEND AS MUCH TIME AS YOU WANT ON EACH WORD.

BEFORE GOING TO THE NEXT TEACHING CARD, STORE EACH WORD A MINIMUM

OF TWO TIMES.

* * * * *

TO ASK FOR HELP, PRESS BUTTON 1, SAY "HELP" INTO THE MICROPHONE,

AND THE MONITOR WILL ANSWER YOU.

C. HOW TO LISTEN TO THE RECORDINGS

One of the best ways you have of improving your pronunciation is
listening to both voices speaking the same word, in quick suc-
cession. You can do this with the RECALL button. When you press
the RECALL button, the + at the lower right of the screen dis-
appears, and the teaching machine will play the tape loop through
the loudspeaker for you to hear. The microphone will not be
turned on, since you can only listen with the RECALL button. You
will hear the last recording of your voice which you made with
the STORE button, and then you will hear the teacher's voice
speaking the English word. Can you hear any differences between
the way you speak and the way he speaks?

D. HOW THE TEACHING MACHINE HELPS YOU IMPROVE YOUR PRONUNCIATION

Our system can help you because it gives you a chance to compare
your voice quickly with a correct pronunciation. You can hear
the teacher whenever you are finished speaking with the STORE
button, and you can compare the two voices with the RECALL but-
ton. Listen carefully and pick out any differences between your
voice and the correct pronunciation. Listen to the whole word
and try to get every part of it to sound like the teacher's
voice. When you cannot hear any differences, your pronunciation
is correct.

E. IN CASE OF TROUBLE

The monitor will sit outside and keep watch over the machine to
make sure that it is working normally. If there is trouble of
some kind and he wants to talk to you, he can speak to you over

the loudspeaker. This will interrupt the picture on the screen. You must wait until he is through speaking to answer him. He will tell you when the problem is fixed and will then let you take control of the machine again.

Please do not hesitate to ask questions about <u>anything</u> you feel unsure about!

F. GENERAL LEARNING PROCEDURE

Now you know how to use the teaching machine to help you improve your pronunciation of each of the English words. Before you begin, we still need to tell you the general rules for Part II.

You will find that if the screen says REPEAT, you will not be able to start a new English word with BUTTON 6, because the machine will not respond. You must press STORE and speak the old word one more time to get rid of the REPEAT, and then you can continue with BUTTON 6.

You may know already that when you finish with the 12th teaching card, you can go right back to the first card as your next English word to work on. You can, therefore, go through the stack of 12 words several times during each day's session. You can work at your own pace for most of the time.

We would like you to observe the following rules as you go through the session. When you begin PART II, run through the 12 words rather quickly. Each time you enter a new teaching card, speak the word no more than three times with the STORE button, and use the RECALL button no more than three times.

If you have difficulty with a particular word, note down the problem, if you want, on the note-paper provided. You will have the time to return to work on that word later in the session.

Once you have finished this quick run through the words, you can go back to word 1, press BUTTON 6, and continue normally. Make sure that the cards are in order and that the word numbers on the screen and your cards agree. You can now spend as much time as you want on each word in the stack. The only thing we request is that you STORE each word a minimum of two times before going on to the next word in the stack. Make any notes you wish to help you as you learn. You can go through the pile of words as many times as you want during the session.

If there is an English word that the teaching machine does not seem to be able to help you pronounce correctly, no matter how many times you try it, make sure to tell the Monitor about it. The machine is not perfect yet, and there may be something wrong with it that we can correct before your next session.

Thanks for reading all these instructions! Please feel free to ask any questions you wish at any time. We will leave these instructions in the room with you as you work, so that you can refer to them whenever you want.

Enjoy yourself!

SIGNS IN ENGLISH AND SPANISH TO BE PLACED ON THE APPARATUS

FOR VU METER:
Watch this loudness meter whenever you speak into the microphone.
Keep the needle between the marks.

FOR CRT SCREEN:
You must wait for the + to appear at the lower right corner of
the rectangle before the machine will be ready for new commands.
Make sure that the word numbers on the teaching card and at the
lower left corner of the rectangle always agree. Use BUTTON 7
to correct any differences.

FOR LANGUAGE MASTER:
Wait for the →] signal to appear before starting the card. Leave
the card at the left side while you work on each word; then place
it face down on the table, on top of the other used cards. This
will keep them in order for the next cycle.

FOR MICROPHONE:
Speak with your mouth about 12 inches from here. Wait for the →]
signal to appear on the screen before recording your voice.
Watch the loudness meter as you speak.

FOR BUTTON-BOX
Press the buttons quietly.

PART I: SPEAKING SPANISH WORDS

SISA   PESO   PADRE   COSA   SU

SPEAK THIS LIST TWICE, IN YOUR NORMAL SPEAKING VOICE.

MAKE SURE YOU ARE SATISFIED WITH HOW YOUR VOICE SOUNDS AS YOU

SPEAK.

BUTTON 9: TO BEGIN A NEW SPANISH WORD.

BUTTON 8: TO CORRECT AN OLD SPANISH WORD.

WHEN YOU FINISH THE FIRST RUN THROUGH THE LIST, PRESS BUTTON 9

ONCE, AND BEGIN AGAIN.

* * * * *

PART II: IMPROVING YOUR PRONUNCIATION OF ENGLISH WORDS

BUTTON 6: TO ENTER A NEW TEACHING CARD.

BUTTON 7: TO CORRECT DIFFERENCES BETWEEN WORD NUMBER ON SCREEN

AND ON CARD.

"STORE" BUTTON: TO RECORD YOUR VOICE AND THEN HEAR THE TEACHER.

"RECALL" BUTTON: TO LISTEN TO YOUR LAST RECORDING AND THEN TO

THE TEACHER.

ON YOUR FIRST RUN THROUGH THE STACK OF TEACHING CARDS, "STORE"

AND "RECALL" EACH WORD NO MORE THAN THREE TIMES. WHEN YOU GET

BACK TO WORD 1, YOU CAN SPEND AS MUCH TIME AS YOU WANT ON EACH

WORD.

BEFORE GOING TO THE NEXT TEACHING CARD, STORE EACH WORD A MINIMUM

OF TWO TIMES.

* * * * *

TO ASK FOR HELP, PRESS BUTTON 1, SAY "HELP" INTO THE MICROPHONE,

AND THE MONITOR WILL ANSWER YOU.

SIGNS IN ENGLISH AND SPANISH TO BE PLACED ON THE APPARATUS

FOR VU METER:
Watch this loudness meter whenever you speak into the microphone.
Keep the needle between the marks.

FOR CRT SCREEN:
You must wait for the + to appear at the lower-right corner of
the rectangle before the machine will be ready for new commands.
Make sure that the word numbers on the teaching card and at the
lower-left corner of the rectangle always agree. Use BUTTON #7
to correct any diff-rences.

FOR LANGUAGE MASTER:
Wait for the →] signal to appear before starting the card. Leave
the card at the left side while you work on each word; then place
it face down on the table, on top of the other used cards. This
will keep them in order for the next cycle.

FOR MICROPHONE:
Speak with your mouth about 12 inches from here. Wait for the →]
signal to appear on the screen before recording your voice. Watch
the loudness meter as you speak.

FOR BUTTON-BOX:
Press the buttons quietly.

95

10 July 1970

Here are the instructions which you read during your first
session with the teaching machine. As you remember, the
instructions were so complicated that you had to spend most
of your time in reading them and beginning to use the equip-
ment. We expected that learning would take time, but we
want to make it easier for you during the coming sessions.

If you study the enclosed instructions carefully before you
come again, you will be able to spend all of your time in
the next session in improving your pronunciation. This
copy is yours to keep; make any notes you want on it, and
ask me any questions that you might have about them when
you return.

There is one request that I have about these instructions
and about the whole teaching system: PLEASE don't discuss
them with any other participants in the learning, and don't
spread the details about what you're doing among your other
friends. There are different procedures being used, and you
could confuse other students; we might also need more stu-
dents in the future, and we couldn't employ a student who
had heard about what we're doing in the wrong way. Thanks
for your attention to the enclosed instructions and to the
above requests.

See you soon!

Sincerely yours,

Daniel N. Kalikow

96

2.7.4   Appendix D: Spanish-Language Version of the Text
                       in Appendix C

The same order of presentation is used in this appendix. Ss
always read the Spanish translations and never the English. The
only exception to this is in the signs placed on the apparatus:
Spanish is at the top, and the English equivalent is directly
beneath.

INTRODUCCION AL EQUIPO DE ENSEÑANZA

Como Ud. bien sabe tenemos un nuevo equipo de ensenanza cuyo propós-
ito es el de mejorar la pronunciación del inglés de gente de habla
española. Deseamos familiarizarlo con diversas partes de este
equipo. Ud. será capaz de aprender más rapidamente si entiende
como trabajan las partes de la máquina entre si y para beneficio
de Ud. El equipo puede parecer complicado cuando se leen las in-
strucciones por primera vez pero Ud. verá que después de unos pocos
minutos de experiencia, Ud. estará usando la máquina de ensenanza
casi automáticamente, mejorando su pronunciación del inglés y divir-
tiéndose a la vez! Si Ud. tuviera algunas preguntas después de leer
esto, tendremos mucho gusto en responderlas en cualquier momento.

Nuestra máquina de ensenanza ocupa dos salas: una para el estudi-
ante y otra para algún equipo extra y para el Monitor quien se en-
cuentra allí para asegurarse de que el equipo está trabajando OK.
En la sala del Monitor hay una computadora que controla el resto
del equipo respondiendo a sus comandos desde la sala del estudiante
y hay también una grabadora que se escucha en dicha sala. Esta
grabadora tiene solmenteun pequeño rollo de cinta en vez de un rollo
grande. Cada vez que Ud. la enciende, da una vuelta y ello toma
alrededor de cinco segundos. Ud. puede grabar su propia voz en la
cinta y también puede escuchar la voz grabada de su profesor en la
misma. Ud. puede escuchar o grabar con la cinta cuantas veces desee
mientras que su pronunciación mejora.

En la sala del estudiante hay varias piezas de quipo que Ud. usará
mientras que aprende.

1. CAJA DE BOTONES - Cuano Ud. desee hacer cualquier cosa con la
máquina de enseñanza, debe pedirle ayuda a la computadora. Como la

98

computadora no es muy inteligente, solamente responderá a un
pequeño número de instrucciones teniendo Ud. que traducir sus
instrucciones presionando botones para que entienda. Ud. puede
empezar cada actividad presionando uno de los doce botones de la
caja. En páginas de instrucciones subsiguientes se le dára más
detalles sobre cual botón corresponde a cada actividad.

Es importante que Ud. siempre presione los botones lo más silen-
ciosamente posible. Cuando haya decidido cual botón va a presionar,
coloque la punta de su dedo ligeramente sobre el botón sin ejercer
presión. Luego presione suavemente y suelte calmadamente. Es
especialmente importante que Ud. suelte el botón con calma. No
tiene que presionar el botón con gran fuerza; simplemente hágalo
tocar el fondo. Tampoco debe soltar el botón bruscamente. Por lo
general, simplemente librando la presión de su dedo hará que el
resorte que se encuentra debajo del botón le eleve el dedo calma-
damente. Este método es importante pero no se preocupe; cuando menos
lo piense sera automático y Ud. no tendrá ni siquiera que pensar en
él!

2. PANTALLA DE VISION - La computadora dibuja cosas en esta pantalla
para informarle sobre lo que está sucediendo durante la lección. Es
como una pantalla de TV pero las "imágenes" que Ud. ve son mucho más
sencillas, pudiendo Ud. cambiarlas por lo que Ud. hace mientras
aprende. En instrucciones posteriores se le dirá lo que cada imagen
significa y lo que puede hacer Ud. para cambiarlas.

3. MICROFONO - Esto es por supuesto en lo que Ud. habla. Cuando
Ud. desea grabar una palabra debe instruirle a la computadora que
encienda el micrófono. Esto lo hace Ud. presionando con calma uno
de los botones de la caja de botones. Más adelante se le dan in-
strucciones que le dicen cuáles botones debe usar. Después que Ud.
presiona el botón debido, la computadora le indica que el micrófono

está listo retirando cualquier imagen que se encuentre en la pantalla y reemplazándola con una imagen que se ve así: +]. Esta es su señal para que hable. Permanecerá solamente unos dos segundos y por lo tanto Ud. debe hablar apenas vea la señal +] en la pantalla.

4. INDICADOR DE VOLUMEN - Cuando Ud. habla por el micrófono, su voz no deberá ser ni muy alta ni muy baja pues de lo contrario, la computadora no podrá "entender" lo que Ud. ha dicho. El indicador de volumen se mueve en respuesta a su voz cuando el micrófono está encendido; cuanto más alta sea su voz, más se mueve. Observe la aguja mientras que habla.

5. TARJETAS DE ENSEÑANZA - Cada vez que Ud. venga, estudiará la pronunciación de un cierto grupo de palabras en inglés. Ud. recibirá ayuda al hacer esto ya que hemos grabado la voz de un profesor pronunciando las palabras que Ud. va a estudiar pudiendo escuchar la voz del profesor cuando Ud. desee. Antes de comenzar el trabajo de cada día, Ud. recibirá una serie de tarjetas, cada una de las cuales estará numerada y tendrá una palabra escrita en la esquina superior derecha y un pedazo de cinta grabadora a lo largo de la parte inferior. La voz del profesor está grabada en la cinta y Ud. la puede escuchar usando la máquina que lee tarjetas.

6. MAQUINA PARA LEER TARJETAS - El propósito de esta máquina es transferir la grabación de la voz del profesor al rollo de cinta del exterior de modo que Ud. pueda escucharla. Más adelante se le darán instrucciones para el uso de esta máquina.

7. PARLANTE - Esto es por supuesto por donde Ud. escucha las grabaciones de su voz y la del profesor. De vez en cuando, si está teniendo dificultades, el Monitor interrumpirá la sesión y le hablará también por el parlante. Ud. puede responderle por el micrófono. Cuando el problema haya sido resuelto, el Monitor apagará el parlante y le devolverá a Ud. el control de la máquina.

Sírvase hacer cualquier pregunta sobre estas instrucciones ya que nosotros se la responderemos gustosamente.

100

INTRODUCCION A LA SESION DE HOY

La sesión de hoy será deferente de la acostumbrada. Tenemos una
gran cantidad de palabras en inglés que desearíamos que Uds. nos
pronunciaran. Mosotros grabaremos su voz y usaremos esta grabación
para medir el progreso que Ud. haga a través del uso de esta
máquina. El monitor permanecerá en la sala del estudiante hoy y
llevará a cabo la mayor parte de las cosas complicadas. Todo lo
que Ud. debe hacer es pronunciar las palabras por el micrófono.

La sesión de hoy día consistirá de tres partes: Parte I, en la
cual Ud. pronunciará una lista corta de palabras en español;
Parte II, en la cual Ud. pronunciará algunas palabras en inglés;
y Part III, en la cual Ud. leerá algunas oraciones en inglés.

La Parte I se hará exactamente de la misma manera como en todas
las futuras sesiones de aprendizaje. Después que Ud. haya comple-
tado la Parte I, leerá un poco más sobre la Parte II y Parte III.

PARTE I: PRONUNCIACION DE LAS PALABRAS EN ESPAÑOL

El propósito de esta parte es el de introducir su voz a la máquina.
Como toda persona tiene voz diferente, la máquina tiene que saber
como es las suya para que le mejore su pronunciación.   Queremos que
Ud. hable algunas palabras en español ahora, ya que sabemos que Ud.
las puede pronunciar correctamente.   Es muy importante que Ud. hable
normalmente en la Parte I ya que debemos medir cualquier mejora en
su inglés con respecto a estas palabras en español.

He aquí una lista de cinco palabras en español que Ud. grabará en
la Parte I.   Ud. las grabará dos veces: Una como práctica y luego
una vez más.   El orden en el cual la máquina de enseñanza espera que
Ud. grabe es:

SISA   PESO   PADRE   COSA   SU

He aquí una serie de pasos que Ud. debe seguir para completar la
Parte I.   Si Ud. las lee y las sigue cuidadosamente, no debe tomarle
más que unos cuantos minutos.

PASO 1.   Ud. notará que hay un símbolo + en el centro de la pantalla.
Esto significa que la máquina espera que Ud. comience al principio de
la lista grabando la palabra SISA.   Continue con el Paso 2.

PASO 2.   Grabe la correcta palabra en español.   He aquí como: Pres-
ione el BOTON 9 con un movimiento lento y suave.   Esto retirará cual-
quier imagen de la pantalla y la reemplazará con la señal →], indi-
cando que el micrófono está encendido.   Tiene Ud. luego, unos cuantos
segundos para pronunciar la palabra en español.   Observe el indicador
de Volumen mientras habla.

Cuando el micrófono se apaga, la señal →] desaparece siendo reem-
plazada con una imagen más complicada.   En la parte inferior izquier-
da del rectángulo grande, la computadora le indica que palabra en

102

español espera que Ud. diga. En el centro dice OK ó REPEAT
(REPITA); y en la parte inferior derecha aparecerá un símbolo +
para indicarle que puede proceder.

Ahora Ud. debe efectuar las acciones que se indican a continuación:

A. Si la pantalla dice REPEAT: Ud. debe ir inmediatamente
al PASO 3.

B. Si la pantalla dice OK: Continúe a la pregunta C.

C. ¿Pronunció Ud. la palabra escrita en la parte inferior
izquierda de la pantalla?

1. Sí, lo hice: Continúe a la pregunta D.

2. No, no lo hice: Ud. debe ir inmediatamente al PASO 3.

D. ¿Cuando Ud. pronunció la palabra en español, fue ésta su
pronunciación normal de dicha palabra y le sonó su voz OK?

1. Sí, mi voz fue normal: Vaya al PASO 4.

2. No, había algo malo: Vaya al PASO 3.

PASO 3. Ud. ingresa a este paso pues hay algo mal en la manera como
Ud. ha pronunciado una palabra en español. Ud. desea recibir otra
opción para pronunciar la misma palabra y por lo tanto desea que la
máquina encienda el micrófono aun cuando ella espera que Ud. pronuncie
la palabra antigua. He aquí como: Presione el BOTON 8 con un movi-
miento lento y suave. Esto retirará cualquier imagen de la pantalla
y la reemplazará con la señal →], indicando que el micrófono está
encendido. Pronuncie la antigua palabra en español por el micrófono,
observando el medidor de volumen mientras habla.

Ahora Ud. debe efectuar las acciones que se indican a continuación.

A. Si la pantalla dice REPEAT: Ud. debe regresar al comienzo
del PASO 3.

B. Si la pantalla dice OK: Continúe a la pregunta C.

C. ¿Pronunció Ud. la palabra escrita en la parte inferior
   izquierda de la pantalla?

   1. Sí, lo hice: Continue a la pregunta D.

   2. No, no lo hice: Regrese al comienzo del PASO 3.

D. ¿Cuando Ud. pronunció la palabra en español, fue ésa su
   pronunciación normal de dicha palabra y le sonó su voz OK?

   1. Sí, mi voz fue normal: Vaya al PASO 4.

   2. No, había algo malo: Regrese al comienzo del PASO 3.

PASO 4. Cuando Ud. llega a este paso, significa que Ud. acaba de
grabar una palabra en español exitosamente. Tanto Ud. como la máquina
de enseñanza estuvieron de acuerdo con la manera como sonó la palabra.
Ahora Ud. debe efectuar las acciones que se indican a continuación.

   A. ¿Ha Ud. terminado alguna de las siguientes palabras en
      español: SISA, PESO, PADRE o COSA?

      1. Sí, acabo de terminar una de estas palabras: Esta Ud.,
         entonces, listo para comenzar a trabajar con la siguiente
         palabra de la lista. Regrese al PASO 2 y trabaje con
         la nueva palabra en español.

      2. No, acabo de terminar la palabra SU: ¿Qué hago ahora?

Recuerde que el plan en la Parte I consiste en que Ud. grabe la lista
de cinco palabras en español dos veces.

   A. Si Ud. ha terminado con SU y ésta es su primera pasada por
      la lista de cinco palabras en español, presione el BOTON 9
      solamente una vez y no diga nada.

104

Esto borra la pantalla y coloca un símbolo + en su
centro. Regrese al PASO I.

B. Si Ud. ha terminado con SU y ésta es su segunda pasada
por la lista de cinco palabras en español, lo felicitamos!
Ud. acaba de completar la Part I y puede continuar con el
resto de las actividades de hoy.

El BOTON 8 y el BOTON 9 no se usan otra vez hoy. Ellos son usados
en la Parte I.

¿QUE QUIERE DECIR CUANDO EN LA PANTALLA APARECE "REPEAT"?

Ud. ha presionado un botón que debía encender el micrófono y permitirle pronunciar una palabra a la máquina de enseñanza. La señal →] apareció en la pantalla y ahora la palabra REPEAT aparece escrita en la parte inferior del rectángulo en la pantalla. ¿Qué quiere decir?

No quiere decir que Ud. ha pronunciado la palabra incorrectamente. La máquina no es tan inteligente! Lo que sí significa es que las computadora no pensó que lo que escuchó era una palabra. Existen varias cosas que pueden dar origen a un REPEAT.

1. Ud. no dijo nada mientras que el micrófono estabe encendido. Una vez que la señal →] aparece en la pantalla, Ud. tiene solamente alrededor de dos segundos para pronunciar la palabra. Si espera demasiado, el micrófono se apagará muy temprano. Asegúrese de que Ud. empiece a hablar en el mismo instante que aparece la señal →] en la pantalla!

2. Ud. empezó a pronunciar la palabra muy temprano y se encontraba diciéndola cuando la señal →] apareció en la pantalla. No se olvide de esperar que apaiezca la señal →] antes de comenzar a pronunciar la palabra.

3. Hubo un corto ruido mientras que el micrófono estaba encendido, antes de que Ud. pudiese hablar. Si el ruido es lo suficientemente fuerte, la máquina piensa que es la palabra y para el micrófono. Es muy importante que el único sonido después de que aparezca la señal →] sea su voz pronunciando la palabra. Es por ello que Ud. debe presionar el botón con la mayor calma posible.

4. Su voz fue demasiado suave al pronunciar la palabra.
¿Está Ud. sentado de tal manera que su boca se encuentre a
más de doce pulgadas del micrófono? Observe el indicador
de volumen mientras que habla y asegúrese de que su voz haga
pasar a la aguja sobre la marca inferior.

5. Su voz fue demasiado fuerte al pronunciar la palabra.
¿Está Ud. sentado demasiado cerca al micrófono? Observe el
indicador de volumen mientras que habla y asegúrese de que
su voz no hace pasar a la aguja sobre la marca superior.

PARTE II: PRONUNCIACION DE LAS PALABRAS EN INGLES

Ahora estamos listos para que Ud. pronuncie una lista de varias palabras en inglés. Esto le será muy sencillo ya que todo lo que tiene que hacer es presionar un botón y pronunciar cada palabra en inglés. El monitor hará todo lo demás. Usaremos el siguiente procedimiento para todas las palabras.

PASO 1. El monitor toma una nueva tarjeta de enseñanza, presiona el BOTON 6, espera que aparezca la señal →] en la pantalla y coloca la tarjeta en la máquina para leer tarjetas. Ud. todavía no escuchará la grabación de la voz del profesor. La palabra que Ud. pronunciará está impresa en la esquina superior derecha de la tarjeta de enseñanza.

PASO 2. Una vez que se ha introducido la nueva tarjeta de enseñanza, habrán algunos números que cambian lentamente en la esquina inferior derecha de la pantalla. Los números se harán más pequeños y finalmente son reemplazados con un símbolo +. Esto quiere decir que la máquina está ahora lista para que Ud. pronuncie la palabra en inglés impresa en la tarjeta de enseñanza.

PASO 3. Antes de hablar, Ud. debe indicarle a la máquina que encienda el micrófono. Usando un movimiento lento y suave, presione el botón marcado STORE. Esto borrará la pantalla y colocará la señal →] en ella, indicando que Ud. puede hablar ahora. No se preocupe sobre una mala pronunciación de la palabra; Ud. recibirá una segunda opción poco después. Observando el medidor de volumen pronuncie la palabra en inglés que está escrita en la tarjeta de enseñanza. Recuerde que Ud. solamente tiene unos pocos segundos para pronunciar la palabra después de presionar el boton STORE y por lo tanto debe empezar a hablar apenas aparece la señal →] en la pantalla.

PASO 4. Ahora una de dos cosas puede suceder:

A. Si la pantalla dice REPEAT: Hubo algo malo en la forma como Ud. pronunció la palabra. No escuchará al profesor pronunciar la palabra hasta que Ud. lo haga y hasta que en la pantalla no diga REPEAT. Espere que aparezca el símbolo + en la parte inferior derecha de la pantalla y luego regrese al comienzo del Paso 3.

B. Si la pantalla no dice REPEAT: La máquina está satisfecha con lo que Ud. dijo. Ud. escuchará ahora la voz del profesor pronunciando la palabra en inglés. Escuche su pronunciación cuidadosamente pues Ud. tendrá otra oportunidad de pronunciar la palabra poco después. Despues que el profesor ha terminado de hablar, espere que el símbolo + vuelva a aparecer en la parte inferior derecha de la pantalla y luego continue al Paso 5.

PASO 5. Ud. ha pronunciado la palabra ahora por lo menos una vez y ha escuchado al profesor decirla una vez. Ahora puede pronunciarla nuevamente. Con un movimiento lento y suave, presione el botón STORE y use el mismo procedimiento del Paso 3 para pronunciar la palabra una vez más.

PASO 6. Ahora puede suceder una de tres cosas:

A. Si la pantalla dice REPEAT: Espere a que vuelva a aparecer el símbolo + en la parte inferior derecha de la pantalla y luego regrese al Paso 5.

B. Si Ud. piensa que puede pronunciar mejor la palabra en inglés, que no se estaba concentrando o que su voz no sonó "bien", a su parecer: regrese al Paso 5.

C. Si Ud., el monitor y la máquina fueron satisfechos, podemos pasar a la siguiente palabra en inglés de la lista. Regrese al Paso 1.

109

PARTE III: LECTURA DE ORACIONES EN INGLES

Desearíamos grabar su voz mientras Ud. lee algunas oraciones
en inglés. Nosotros sabemos que leer inglés no es fácil si
Ud. no está seguro de como se pronuncia el inglés escrito, asi
que haga lo mejor que pueda y no se preocupe de cometer errores.

Antes de empezar a leer en voz alta, el monitor le entregará
un papel con las oraciones en inglés que Ud. debe leer. El
las leerá en voz alta, mientras Ud. lo sigue leyéndolas silen-
ciosamente. Cuando él encienda el micrófono Ud. leerá entonces
las mismas oraciones a una velocidad y volumen de conversación
normal.

INTRODUCCION A LA SESION DE HOY

Hoy empezaremos la operación normal de la máquine de enseñanza.
Esta sesión consta de dos partes: Parte I, en la cual Ud. pro-
nunciará la misma lista de palabras en español que pronunció en
su primer día y de la misma namera; y Parte II, en la cual Ud.
comienza a usar la máquina de ensenanza para mejorar su pronun-
ciación del inglés. Nosotros le daremos hojas con instrucciones
completas para ambas Partes. Ud. ya ha visto las instrucciones
para la Parte I y por lo tanto ello debe ser fácil.

PARTE II: APRENDIENDO A PRONUNCIAR PALABRAS EN INGLES

Ud. está listo ahora para comenzar a usar la máquina de enseñanza
para mejorar su pronunciación de palabras en inglés. Se le ha
dado una serie de tarjetas de enseñanza numeradas, las cuales Ud.
puede usar durante el resto de la lección de hoy.

Por la mayor parte, Ud. tiene ahora la libertad de trabajar con
las palabras en inglés a su propio paso. He aquí una descripción
en ingles a su propio paso. He aquí una descripcion de como con-
trolar la máquina de enseñanza y de las reglas generales para la
Parte II que Ud. debe entender.

A. COMO COMENZAR A TRABAJAR EN UNA NUEVA PALABRA EN INGLES:

El primer paso para trabajar en una nueva palabr. en inglés es
decirle a la computadora que Ud. ha terminado con la actividad an-
terior y que desea colocar una grabación de la voz del profesor en
el rollo de cinta donde pueda escucharla. Esto se hace de la
siguiente manera:

PASO 1. Presione el BOTON 6. Esto inicia el proceso y retira cual-
quier imagen de la pantalla. Si ésta es su primera tarjeta de en-
señanza de la serie, salte al PASO 3.

PASO 2. Retire la tarjeta de enseñanza anterior de la ranura de la
máquina y colóquela boca abajo sobre el grupo de tarjetas usadas.

PASO 3. Coloque la siguiente tarjeta de enseñanza en la ranura de
la máquina y deslícela hacia la izquierda hasta que su borde iz-
quierdo esté cerca del triángulo pequeño.

PASO 4. Pocos segundos despues de presionar el BOTON 6, la señal →]
debe aparecer en la pantalla la cual debe encontrarse libre. Esto

11.

no significa que Ud. debe hablar por el micrófono; significa que la computadora está lista para que Ud. inicie la tarjeta de enseñanza. Espere hasta que la señal →] aparezca en la pantalla antes de pasar al PASO 5.

PASO 5. Ahora empuje un poco la tarjeta hacia la izquierda y la máquina la tirará el resto del camino. Cuando la tarjeta se detiene ella permanecerá en el borde izquierdo de la máquina. Déjela allí para que pueda leer la palabra.

PASO 6. Si la máquina no estuviera satisfecha con algo mientras que Ud. ejecutaba el PASO 5, en la pantalla dirá REPEAT. Ud. debe regresar al PASO 1 esquivando, por supuesto, el PASO 2.

PASO 7. Observe cuidadosamente el número de palabra impreso sobre la palabra en inglés de la tarjeta de enseñanza. Ahora observe cuidadosamente el número de palabra en la esquina inferior izquierda de la pantalla. Es muy importante que estos números coincidan ya que es la única manera como la computadora sabe en que palabra está Ud. trabajando. Generalmente, si las tarjetas se mantienen en orden y si Ud. no tiene problemas en introducirlas a la máquina para leer tarjetas, los números estarán siempre de acuerdo.

¿Están de acuerdo ahora?

A. Sí, son el mismo número: Vaya al PASO 8.

B. No, son diferentes: He aquí como se les hace coincidir. Cada vez que Ud. presione el BOTON 7, el número de palabra en la pantalla disminuye en 1. Si Ud. lo presiona dos veces cuando el número original era "10", cambiará de la siguiente manera: "9" - "8". Si Ud. lo presiona tres veces cuando el número original era "2" cambiará de la siguiente manera: "1" - "0" - "12". Por lo tanto, observe la pantalla mientras que presiona el BOTON 7 cuantas veces sea necesario para que los dos números de palabra coincidan.

113

PASO 8. Ud. está listo ahora para empezar a trabajar en la pro-
nunciación de esta palabra en inglés. Ud. todavía no ha escuchado
la voz del profesor pronunciando pero ha transferido la grabación
de su voz de la tarjeta de enseñanza al rollo de cinta del exterior.
Ud. puede escucharla por el parlante cuando desee, mientras que
estudia como pronunciar esta palabra. Pero antes de que Ud. comience
a trabajar en la primera palabra, le pedimos que lea el resto de estas
instrucciones. La sección titulada PROCEDIMIENTO DE APRENDIZAJE GEN-
ERAL le dará algunas reglas y sugerencias para lo que Ud. debe hacer.

B. COMO GRABAR SU VOZ

Cuando Ud. desea grabar su voz en el rollo de cinta, use el botón
STORE. Recuerde: presiónelo con calma, espere la senal →] y
observe el indicador de volumen mientras que pronuncia la palabra
en inglés cuidadosamente.

Si la máquina de enseñanza no dice REPEAT, Ud. escuchará la voz del
profesor pronunciando la palabra en inglés después de Ud. Si no
escucha nada y la pantalla dice REPEAT, Ud. debe repetir este paso;
ningún otro boton funcionará.

Escuche cuidadosamente la voz del profesor mientras que pronuncie
la palabra en inglés. ¿Puede Ud. escuchar algo diferente entre la
manera como el habla y la manera como Ud. acaba de hacerlo?

C. COMO ESCUCHAR LAS GRABACIONES

Una de las mejores maneras de mejorar su pronunciación es escuchar
ambas voces pronunciando la misma palabra de manera rápida y sucesiva.
Ud. puede hacer esto con el botón RECALL. Cuando Ud. presiona el
botón RECALL, el símbolo + en la parte inferior derecha de la pantalla
desaparece y la máquina de enseñanza tocará la cinta a través del
parlante para que Ud. la escuche. El micrófono no se encenderá ya que
que Ud. solamente puede escuchar con el botón RECALL. Ud. escuchará

114

la última grabación de su voz que Ud. hizo con el botón STORE y
luego escuchará la voz del profesor pronunciando la palabra en
inglés.   Puede escuchar Ud. algo diferente entre la manera como
Ud. habla y la manera como lo hace él?

D. COMO PUEDE LA MAQUINA DE ENSEÑANZA AYUDARLE A MEJORAR SU
    PRONUNCIACION

Como Ud. probablemente sabe, el inglés tiene más vocales que el
español. Algunas de ellas son similares a las vocales del español
y algunas son bastante nuevas y diferentes. La mayoría de la
gente de habla española tiene cierto grado de dificultad en pro-
nunciar las vocales del inglés. Existen, por supuesto, varias
otras clases de dificultades que Ud. puede tener al hablar el
inglés. En unas pocas semanas, le explicaremos como usar la má-
quina de enseñanza para ayudarlo en esos problemas. Durante las
siguientes sesiones, mientras que Ud. uas los botones STORE y
RECALL para hacer gradualmente que su pronunciación sea idéntica
a la del profesor, la pantalla le dará información que Ud. puede
usar para mejorar su pronunciación de vocales en inglés.

Cada una de las 12 Tarjetas de Enseñanza contiene una palabra mono-
sílaba en inglés. Nosotros no creemos que Ud. tenga mucha dificul-
tad en pronunciar las consonantes de estas palabras pero pensamos
que Ud. puede encontrar algunas de estas vocales difíciles de pro-
nunciar correctamente. Cada una de las 12 palabras en inglés con-
tiene una vocal diferente. Para pronunciar todas estas vocales
correctamente, sus labios, dientes y lengua deben encontrarse en
los lugares y momentos debidos. Esto parece ser una tarea difícil
de cumplir ya que generalmente hablamos sin pensar en ello. Pero
para mejorar sus vocales en inglés Ud. debe aprender a cambiar sus
hábitos de conversación tratando de hacer cosas nuevas con su boca.

115

Afortunadamente su tarea es simplificada por la naturaleza de las vocales en inglés. En la mayoría de ellas, la posición de los labios y de los dientes no es tan importante como es la posición de la lengua en la boca. Diferentes posiciones de la lengua producen diferentes sonidos de vocales. Cuando la lengua se encuentra arriba y adelante en la boca, se produce una vocal como la I en SISA. Cuando la lengua está abajo y atrás en la boca, se produce una vocal como U en SU.

Algunas vocales en inglés son difíciles de pronunciar pues su entrenamiento en hablar el español jamás ha requerido que coloque su lengua en ciertas regiones de su boca. Ud. puede producir facilmente todas las vocales del espanol sin pensarlo; pero cuando Ud. habla el inglés, Ud. usa algo parecido a las posiciones de las vocales del espanol y el resultado de esta sustitución es un acento. Si Ud. pudiera aprender nuevas maneras de mover su lengua, Ud. prodría mejorar su acento español considerablemente. Desafortunadamente este tipo de nuevo aprendizaje es difícil para la mayoría de la gente ya que por lo general hablamos sin pensar en las cosas que tenemos que hacer al pronunciar las palabras. Pero Ud. tiene la máquina de enseñanza para guiarlo en este aprendizaje. Ella le puede decir como cambiar la posición de su lengua para mejorar sus vocales.

Cada vez que Ud. pronuncia una palabra por el micrófono, la máquina de enseñanza buscará la parte de la vocal de la palabra. Cuando ella le escucha pronunciar una vocal, empieza a calcular en que lugar de su boca se encuentra su lengua. Ella determina esta posición cada centésimo de segundo hasta que Ud. termina de pronunciar la vocal. Cuando Ud. ha terminado con la palabra y el micrófono es apagado, ella le muestra en la pantalla el lugar donde se encontraba su lengua mientras que pronunciaba la palabra.

El rectángulo grande en la pantalla es una simple representacion de una vista lateral izquierda de la boca - orientado como el rectángulo en la figura del frente del parlante. La máquina de

enseñanza le muestra donde se encontraba su lengua colocando una
serie de puntos en el rectángulo. El punto brillante es la posi-
ción de su lengua al comienzo de la vocal y cada punto sucesivo es
su posición en cada centésimo de segundo sucesivos hasta el final
de la vocal. Si los puntos están amontonados cerca de la esquina
superior izquierda, esto quiere decir que su lengua estaba arriba
y adelante en su boca. Por lo tanto Ud. puede usar esta figura para
obtener información sobre la ubicación de su lengua mientras que
pronuncia vocales. Ahora: ¿Cómo sabe Ud. como cambiar su pronun-
ciacion para mejorarla y cómo sabe Ud. cuando está bien?

Ud. notará que dentro del rectángulo grande hay un rectángulo más
pequeño, además de la serie de puntos. Esto se llama un blanco.
Existen 12 blancos diferentes, uno para cada palabra en inglés.
Cada uno de ellos indica la región de su boca donde su lengua debería
encontrarse para la correcta pronunciación de cada vocal en inglés.

Si el trazo de puntos no toca el blanco en absoluto, la máquina de
enseñanza le está diciendo que Ud. está pronunciando incorrectamente
la vocal y que debe tratar de mejorar. Puede usar las posiciones
relativas del trazo y del blanco para darse cuenta de como cambiar
la posición de su lengua para su proxima tentativa. Si el trazo
está justo sobre el blanco, su lengua está demasiado arriba. Si el
trazo está a la derecha del blanco su lengua está demasiado atrás.
La próxima vez que Ud. pronuncie la palabra, trate de mover su lengua
a la posición indicada por el blanco.

Es fácil darse cuenta cuando Ud. está equivocado - el trazo de la
lengua no toca el blanco. Es un poco mas difícil ver cuando uno
está verdaderamente correcto ya que toma cierto juicio de su parte.
Aún cuando está muy bien que su trazo dé en el blanco, es aún mejor
que Ud. pueda tocar el mismo centro del blanco con alguna parte du
su trazo. Debemos decirle que habrán blancos que Ud. podrá tocar con
las justas aún con un aprendizaje prolongado y Ud. jamás podrá tocar
sus centros. Pero Ud. debe tratar de hacer esto todo el tiempo,

cuando sea posible.   Por favor note que no hemos dicho que todo el
trazo debe estar dentro del blanco; solamente que es suficiente
que su trazo toque el centro del blanco.

Ud. también debe asegurarse de que pueda darle al blanco de manera
consistente.   No es suficiente el que Ud. pudiera producir un trazo
perfecto una vez.   Puede Ud. repetir esto cuando lo desee?

He aquí otra cosa muy importante que no debe olvidarse. Cuano Ud.
esté usando este sistema, no dependa totalmente de las figuras de
posición de la lengua. Recuerde sus oídos! Se supone que su pro-
nunciación de las palabras son idénticas a la voz del profesor y las
figuras son solamente para ayudarle a aprender los sonidos de vocales
correctos. Si su trazo da en el blanco satisfactoriamente, ello no
quiere decir que su pronunciación es totalmente perfecta. Escuche
toda la palabra y trate de que todo el sonido sea como el de la voz
del profesor.

E.   USO DEL BOTON DE IMAGEN CONTINUA

Habrán veces cuando Ud. esté interesado solamente en darla una mirada
rápida al trazo de la lengua mientras que Ud. habla por el micrófono
y cuando Ud. no desea tomarse todo el tiempo que se necesita cuando
usa el botón STORE. Ud. puede desear pronunciar la palabra de
varios modos diferentes ó puede tan solo desear probar algunos sonidos
de vocales ó posiciones de la lengua ligeramente diferentes. Esto
es posible usando el BOTON 1. Cuando Ud. presiona el BOTON 1, 'el
símbolo + de la parte inferior derecha de la pantalla desaparece ye
el micrófono se enciende. Cualquier sonido que Ud. produzca es ahora
recogido por la máquina de enseñanza; y cuando ella escucha un sonido
de vocal colocará una serie de puntos indicadores de posición de la
lengua en la pantalla justamente mientras Ud. está hablando.   Ud.
puede probar ahora varias palabras ó vocales diferentes pronunciadas
rápida y sucesivamente. He aquí algunas sugerencias para el uso del
BOTON 1.

118

Ud. se encuentra trabajando para mejorar su pronunciación de alguna palabra en inglés. El blanco para el sonido de vocal de esa palabra se muestra en la pantalla. Pronuncie toda la palabra por el micrófono y observe la pantalla. Mientras que Ud. está pronunciando la parte de la vocal, ejercite con diversas posiciones de la lengua que sean diferentes de las normales. Trate de mover el trazo de modo que lo acerque al blanco cada vez que pronuncie la palabra. Si esto no funciona, es posible que Ud. esté trabajando con una vocal en la que la posición de sus labios ó dientes es de importancia. Pronuncie la palabra unas veces más y trate de cambiar la forma de sus labios ó dientes mientras que pronuncia la vocal. ¿Acerca esto el trazo al blanco?

Otra forma de usar el BOTON 1 es hacer una serie continua de ruidos con su garganta y pronunciar unicamente la parte de la vocal de la palabra. Trate de llevar a cabo los pequeños experimentos que hemos mencionado. ¿Puede Ud. hacer un sonido de vocal que coloca el trazo en el blanco? Si Ud. ve que puede, trate entonces de pronunciar toda la palabra colocando en ella el correcto sonido de vocal.

Mientras que Ud. usa el BOTON 1 y prueba estos nuevos sonidos, recuerde que debe trabajar unicamente para que el trazo de la vocal toque el blanco que ahora se encuentra en la pantalla. Pruebe sonidos de vocal que sean algo similares al que Ud. está pronunciando. Ud. puede, si lo desea, tratar otras palabras en inglés que tengan la misma vocal pero debería trabajar más en la palabra en inglés que se encuentra en la presente tarjeta de enseñanza. Si la vocal es EE, no trate de pronunciar OO, ya que el trazo de dicha vocal no aparecerá correctamente en la pantalla. Pero si la palabra en inglés es BEET, Ud. puede tratar diferentes sonidos de EE y quizás la palabra FEET ó algo parecido.

Es posible que Ud. no pueda tocar el blanco mientras que usa el BOTON 1 y que pueda hacerlo mientras que usa el procedimiento STORE normal. O la diferencia puede ser invertida. Esto se debe a que hay algunas

119

pequeñas diferencias entre los dos botones. El BOTON 1 es para
que Ud. se de una idea general de como debería cambiar su pronunci-
ación para que toque el blanco cuando pronuncie la palabra en STORE.
Nosotros estamos más interesados en que Ud. pueda tocar el blanco
mientras que Ud. pronuncia la palabra con el botón STORE así que
use el BOTON 1 solo cuando verdaderamente lo puede ayudar.

Cuando Ud. desea pasar a otra actividad, debe indicarle a la comp-
utadora que apague la imagen contínua y que se prepare para un nuevo
comando de STORE ó RECALL. No se olvide que el símbolo + de la parte
inferior derecha de la pantalla debe estar presente para que estos
botones trabajen y que presionando el BOTON 1, el símbolo + desaparece.
Para regresar a la operación normal, presione el BOTON 0, el cual
reemplazará el símbolo + y le permitirá pasar a su siguiente comando.
Recuerde: una vez que Ud. ha presionado el BOTON 1, debe presionar
el BOTON 0 antes de que la máquina pueda escuchar cualquier otro
comando.

F. EN CASO DE PROBLEMAS

El monitor estará sentado afuera y observará la máquina para asegu-
rarse de que está funcionando normalmente. Si hubiera problema de
cualquier clase y quisiera hablarle a Ud., él puede hacerlo por el
parlante. Esto interrumpirá la imagen de la pantalla. Ud. debe
esperar a que él termine antes de contestarle. El le dira cuando el
problema ha sido solucionado y luego le permitirá reasumir control de
la máquina.

Por favor no deje de hacernos cualquier pregunta sobre cualquier
cosa de la cual no está seguro!

G. PROCEDIMIENTO DE APRENDIZAJE GENERAL

Ud. sabe ahora como usar la máquina de enseñanza para que lo ayude
a mejorar su pronunciación de cada una de las palabras en inglés.

Antes de que comience, debemos decirle cuales son las reglas generales para la Parte II.

Ud. se dará cuenta de que si la pantalla dice REPEAT, no podrá comenzar una nueva palabra en inglés con el BOTON 6 porque la máquina no responderá. Ud. debe presionar STORE y pronunciar la palabra antigua una vez más para deshacerse del REPEAT, pudiendo luego continuar con el BOTON 6.

Ud. puede ya saber que cuando termina con la doceava tarjeta de enseñanza, Ud. puede regresar a la primera tarjeta como si ella fuera la primera palabra en inglés en la cual Ud. va a trabajar. Por lo tanto, puede usar la serie de 12 palabras varias veces durante la sesión de cada día. Durante la major parte del tiempo puede trabajar a su propio paso.

Nosotros desearíamos que Ud. observe las siguientes reglas durante la sesión. Cuando comience la PARTE II, pase por las 12 palabras rapidamente. Cada vez que Ud. empieza en una nueva tarjeta de enseñanza, no pronuncie la palabra más de tres veces con el botón STORE y no use el botón RECALL más de tres veces. Si desea, use el BOTON 1 pero no más de un minuto. Si Ud. tiene dificultad con alguna palabra en particular, anote el problema, si lo desea, en el papel provisto. Ud. tendrá tiempo de regresar a trabajar en esa palabra más adelante en la sesión.

Una vez que Ud. ha terminado esta pasada rápida de las palabras, puede regresar a la palabra uno, presione el BOTON 6 y continue normalmente. Asegúrese de que las tarjetas estén en orden y de que los números de palabra en la pantalla coincidan con los de sus tarjetas. Ud. puede ahora pasar todo el tiempo que desee en cada palabra de la serie. Lo único que le pedimos es que STORE cada palabra un mínimo de dos veces antes de pasar a la siguiente palabra de la serie. Haga cualquiera anotación que desee para ayudarlo mientras que aprende. Ud. puede repasar la serie de palabras cuantas veces lo desee durante la sesión.

121

Si hay alguna palabra en inglés que la máquina de enseñanza no
parece ser capaz de ayudarlo a pronunciar correctamente, cuantas
veces lo trate, asegúrese de que el Monitor se entere de ello.
La máquina todavía no es perfecta y puede haber algo malo en ella
que podamos corregir antes de su próxima sesión.

Muchas gracias pro leer estas instrucciones! Por favor no deje
de hacernos cualquier pregunta cuando lo desee. Dejaremos estas
instrucciones en la sala mientras que trabaja, de modo que Ud.
pueda referirse a ellas cuando lo desee.

Diviértase!

PART I: PRONUNCIACION DE LAS PALABRAS EN ESPAÑOL

SISA   PESO   PADRE   COSA   SU

PRONUNCIE ESTA LISTA DOS VECES, USANDO SU VOZ NORMAL.
ASEGURESE DE QUE QUEDE SATISFECHO CON LA MANERA COMO SUENA SU VOZ
    MIENTRAS HABLA.

BOTON 9: PARA EMPEZAR UNA NUEVA PALABRA EN ESPAÑOL.

BOTON 8: PARA CORREGIR UNA ANTIGUA PALABRA EN ESPAÑOL.

CUANDO TERMINE DE PRONUNCIAR LA LISTA POR PRIMERA VEZ, PRESIONE EL BOTON 9
    UNA VEZ Y COMIENCE NUEVAMENTE.
                        * * * * * * * * * *
PART II: MEJORAMIENTO DE SU PRONUNCIACION DE LAS PALABRAS EN INGLES

BOTON 6: PARA COLOCAR UNA NUEVA TARJETA DE ENSEÑANZA.

BOTON 7: PARA CORREGIR DIFERENCIAS ENTRE EL NUMERO DE PALABRA EN LA
                PANTALLA Y EN LA TARJETA.

BOTON "STORE" ("GRABAR"): PARA GRABAR SU VOZ Y LUEGO ESCUCHAR AL PROFESOR.

BOTON "RECALL" ("ESCUCHAR"): PARA ESCUCHAR SU ULTIMA GRABACION Y LUEGO
                AL PROFESOR.

BOTON 1: PARA COMENZAR UNA OPERACION DE IMAGEN CONTINUA.

BOTON 0: PARA REGRESAR A UNA OPERACION NORMAL DESPUES DE LA DE IMAGEN CONTINUA.

EN LA PRIMERA PASADA QUE LE HAGA AL GRUPO DE TARJETAS DE ENSEÑANZA, "STORE"
    Y "RECALL" CADA PALABRA NO MAS DE TRES VECES.

NO USE EL BOTON 1 POR PERIODOS DE MAS DE UN MINUTO APROXIMADAMENTE.

REGRESE A LA PALABRA UNO, PUEDE PASARSE TODO EL TIEMPO QUE DESEE EN CADA
    PALABRA.

ANTES DE PASAR A LA SIGUIENTE TARJETA DE ENSEÑANZA, "STORE" CADA PALABRA
    UN MINIMO DE DOS VECES.
                        * * * * * * * * * *

PARA PEDIR AYUDA, PRESIONE EL BOTON 1, DIGA "HELP" POR EL MICROFONO Y EL
    MONITOR LE CONTESARA.

123

la última grabación de su voz que Ud. hizo con el botón STORE y luego escuchará la voz del profesor pronunciando la palabra en inglés. Puede escuchar Ud. algo diferente entre la manera como Ud. habla y la manera como lo hace él?

D. COMO PUEDE LA MAQUINA DE ENSEÑANZA AYUDARLE A MEJORAR SU PRONUNCIACION

Nuestro sistema puede ayudarlo porque le da la oportunidad de comparar rapidamente su voz con una pronunciación correcta. Ud. puede escuchar al profesor cuando termina de hablar con el botón STORE y puede comparar las dos voces con el botón RECALL. Escuche cuidadosamente y distinga las diferencias entre su voz y la pronunciación correcta. Escuche toda la palabra y trate que toda ella suene como la voz del profesor. Cuando Ud. no pueda distinguir alguna, su pronunciación es la correcta.

E. EN CASO DE PROBLEMAS

El monitor estará sentado afuera y observará la máquina para asegurarse de que está funcionando normalmente. Si hubiera problema de cualquier clase y quisiera hablarle a Ud., él puede hacerlo por el parlante. Esto interrumpirá la imagen de la pantalla. Ud. debe esperar a que él termine antes de contestarle. El le dira cuando el problema ha sido solucionado y luego le permitirá reasumir control de la máquina.

Por favor no deje de hacernos cualquier pregunta sobre cualquier cosa de la cual no está seguro!

F. PROCEDIMIENTO DE APRENDIZAJE GENERAL

Ud. sabe ahora como usar la máquina de enseñanza para que lo ayude a mejorar su pronunciación de cada una de las palabras en inglés.

Antes de que comience, debemos decirle cuales son las reglas generales para la Parte II.

Ud. se dará cuenta de que si la pantalla dice REPEAT, no podrá comenzar una nueva palabra en inglés con el BOTON 6 porque la máquina no responderá. Ud. debe presionar STORE y pronunciar la palabra antigua una vez más para deshacerse del REPEAT, pudiendo luego continuar con el BOTON 6.

Ud. puede ya saber que cuando termina con la doceava tarjeta de enseñanza, Ud. puede regresar a la primera tarjeta como si ella fuera la primera palabra en inglés en la cual Ud. va a trabajar. Por lo tanto, puede usar la serie de 12 palabras varias veces durante la sesión de cada día. Durante la mayor parte del tiempo puede trabajar a su propio paso.

Nosotros desearíamos que Ud. observe las siguientes reglas durante la sesión. Cuando comience la PARTE II, pase por las 12 palabras rapidamente. Cada vez que Ud. empieza en una nueva tarjeta de enseñanza, no pronuncie la palabra más de tres veces con el botón STORE y no use el botón RECALL más de tres veces. Si Ud. tiene dificultad con alguna palabra en particular, anote el problema, si lo desea, en el papel provisto. Ud. tendrá tiempo de regresar a trabajar en esa palabra más adelante en la sesión.

Una vez que Ud. ha terminado esta pasada rápida de las palabras, puede regresar a la palabra uno, presione el BOTON 6 y continue normalmente. Asegúrese de que las tarjetas estén en orden y de que los números de palabra en la pantalla coincidan con los de sus tarjetas. Ud. puede ahora pasar todo el tiempo que desee en cada palabra de la serie. Lo único que le pedimos es que STORE cada palabra un mínimo de dos veces antes de pasar a la siguiente palabra de la serie. Haga cualquiera anotación que desee para ayudarlo mientras que aprende. Ud. puede repasar la serie de palabras cuantas veces lo desee durante la sesión.

125

Si hay alguna palabra en inglés que la máquina de enseñanza no parece ser capaz de ayudarlo a pronunciar correctamente, cuantas veces lo trate, asegúrese de que el Monitor se entere de ello. La máquina todavía no es perfecta y puede haber algo malo en ella que podamos corregir antes de su próxima sesión.

Muchas gracias por leer estas instrucciones! Por favor no deje de hacernos cualquier pregunta cuando lo desee. Dejaremos estas instrucciones en la sala mientras que trabaja, de modo que Ud. pueda referirse a ellas cuando lo desee.

Diviértase!

126

PART I: PRONUNCIACION DE ____ __ ___ _   __

SISA   PESO   PADRE   COSA   ___

PRONUNCIE ESTA LISTA DOS VECES, USANDO SU VOZ NORMAL.
ASEGURESE DE QUE QUEDE SATISFECHO CON LA FORMA COMO SE LA ESCUCHA
    MIENTRAS HABLA.

BOTON 9: PARA EMPEZAR UNA NUEVA PALABRA EN ESPAÑOL.

BOTON 8: PARA CORREGIR UNA ANTIGUA PALABRA EN ESPAÑOL.

CUANDO TERMINE DE PRONUNCIAR LA LISTA POR PRIMERA VEZ, PRESIONE EL BOTON 9
    UNA VEZ Y COMIENCE NUEVAMENTE.
                    * * * * * * * * * * *
PART II: MEJORAMIENTO DE SU PRONUNCIACION EN LAS PALABRAS MODELO

BOTON 6: PARA COLOCAR UNA NUEVA TARJETA DE ENSEÑANZA.

BOTON 7: PARA CORREGIR DIFERENCIAS ENTRE EL NUMERO DE PALABRA EN LA
          PANTALLA Y EN LA TARJETA.

BOTON "STORE" ("GRABAR"): PARA GRABAR SU VOZ Y LUEGO ESCUCHAR AL PROFESOR.

BOTON "RECALL" ("ESCUCHAR"): PARA ESCUCHAR SU ULTIMA GRABACION Y LUEGO
          AL PROFESOR.

EN LA PRIMERA PASADA QUE LE HAGA AL GRUPO DE TARJETAS DE ENSEÑANZA, "STORE"
    Y "RECALL" CADA PALABRA NO MAS DE TRES VECES.

REGRESE A LA PALABRA UNO, PUEDE PASARSE TODO EL TIEMPO QUE DESEE EN CADA
    PALABRA.

ANTES DE PASAR A LA SIGUIENTE TARJETA DE ENSEÑANZA, "STORE" CADA PALABRA
    UN MINIMO DE DOS VECES.
                    * * * * * * * * * * *

PARA PEDIR AYUDA, PRESIONE EL BOTON 1, DIGA "HELP" POR EL MICROFONO Y EL
    MONITOR LE CONTESARA.

SIGNS IN ENGLISH AND SPANISH TO BE PLACED ON THE APPARATUS

FOR VU METER:
Observe este medidor de volumen cuando hable por el micrófono.
Mantenga la aguja entre las marcas.

FOR CRT SCREEN:
Ud. debe esperar a que aparezca el símbolo + en la esquina
inferior derecha del rectángulo antes de que el equipo esté listo
para recibir nuevos comandos. Asegúrese de que los números de
palabra en la tarjeta de enseñanza estén siempre de acuerdo con
los de la esquina inferior izquierda del rectángulo. Use el
BOTON 7 para corregir cualquier diferencia.

FOR LANGUAGE MASTER:
Espere que aparezca la señal antes de comenzar con la tarjeta.
Deje la tarjeta en el lado izquierdo mientras Ud. trabaja con
cada palabra; luego colóquela del revés sobre la mesa, encima
de las otras tarjetas ya usadas. Esto las mantendrá en orden
para el siguiente ciclo.

FOR MICROPHONE:
Hable con la boca a unas doce pulgadas (30 cm.) de aquí. Espere
que aparezca la señal en la pantalla antes de grabar su voz.
Observe el medidor de volumen mientras habla.

FOR BUTTON-BOX:
Presione los botones con calma.

Le incluyo aquí las instrucciones que Vd. leyó durante su
primera sesión con la máquina de enseñar. Como recordará,
las instrucciones eran tan complicadas que una gran parte
del tiempo fue empleado en leerlas y muy poco en usar el
equipo. Aunque anticipámos que el aprendizaje llevaría
tiempo, quisiéramos hacerlo más fácil para las próximas
sesiones.

Si Vd. estudia cuidadosamente las instrucciones que le
agregamos antes de la próxima sesión, podrá emplear todo
su tiempo en mejorar su pronunciación. Esta copia es para
Vd. Quédesela. Anote sus dudas y comentarios en ella y
pregúnteme acerca de ellos la próxima vez, si lo desea.

Hay una sola cosa que debo pedirle acerca de las instrucciones
y del sistema de enseñanza en general: POR FAVOR no hable
de ellas con ningún otro participante del curso, y no divulgue
los detalles de lo que está Vd. haciendo entre sus amigos.
Las razones para esto son, en primer lugar, que hay
diferentes procedimientos en juego y podrían producirse
confusiones entre Vds., y en segundo lugar, que podríamos
necesitar más estudiantes en el futuro y no podríamos tomar
a uno que pudiese estar prejuiciado acerca del sistema.

Gracias por su atención hacia las instrucciones y hacia lo
que le acabo de pedir.

Hasta pronto!

Sinceramente suyo,

Daniel N. Kalikow

DNK:srs

2.7.5 Appendix E: Spanish Translations of the 48 Training Words
                     for Vowels

	List 1		List 2		List 3		List 4	
1.	BUG	INSECTO	DO	HACER	FACE	CARA	FEET	PIES
2.	DAY	DIA	DOCK	MUELLE	SIT	SENTARSE	SACK	SACO
3.	SOOT	HOLLÍN	DEAD	MUERTO	SAWED	ASSERADO	FIB	MENTIRA
4.	GOT	TENIDO	SAFE	SEGURO	BUD	CAPULLO	TOOK	TOMÓ
5.	BOAT	BOTE	SEE	VER	SAG	DEFORMAR	GOD	DIOS
6.	BID	APUESTA	BOOK	LIBRO	FEED	ALIMENTAR	FUSS	ALBOROTO
7.	BOOT	BOTA	DOG	PERRO	BERT	DIMINUTIVO DE ALBERTO	SET	COLOCAR
8.	DAD	PAPÁ	BIT	PEDAZO	FOOD	COMIDA	DOSE	DOSIS
9.	FED	ALIMENTADO	BIRD	AVE	SOB	LLANTO	BOOED	EXPRESIÓN USADA POR UN PÚBLICO HOSTIL
10.	FUR	PIEL	SO	ASI	SAID	DICHO	SOUGHT	DESEADO, BUSCADO
11.	BEET	REMOLACHA, BETARRAGA	BAD	MALO	SEWED	COSIDO	SIR	SEÑOR
12.	BOSS	PATRON	BUT	PERO	GOOD	BUENO	PHASE	FASE

2.7.6 Appendix F: Prose Material Read by E and Recorded by S
                     on Testing Days

When the sunlight strikes raindrops in the air, they act
like a prism and form a rainbow. A rainbow is a division of
white light into many beautiful colors. It is said that a pot
of gold can be found at the end of a rainbow. Have you ever
looked for that pot of gold?

Teach the girl to serve a cup of tea.

Use a keen blade to peel and cut that tough apple.

A pun is the peak of wit.

Keep him at peace and don't let him punch me.

Men tease and cuss at the pub, and they drink a ton of beer.

A baby bear is a cub, and a baby dog is a pup.

The key man on your team has no peer.

Don't touch that!

Drop your keys into the tub.

It will be difficult to testify that this is the photograph.

I will execute these specific plans, but I do not think that
    you will find them feasible.

You should distinguish between men who meditate and men
    who modify.

Sir, your bad dog bit this dead bird and then took the beet.

A man sewed the boot and sought a sack of food.

The boy bid for the boat, but the man with the book got it.

Do not sob or make a fuss or they will see your face and not
    feed you.

You must wait until the sun has set and the day is over, and
    then you may sit.

3. MODELS OF USER-COMPUTER INTERACTION

3.1 INTRODUCTION

3.2 GENERAL OVERVIEW

    3.2.1 Definition of Approach

    3.2.2 Methodology

3.3 NO-CHOICE EXPERIMENTS

    3.3.1 Overview

    3.3.2 Detailed Description and Results

    3.3.3 Conclusions

3.4 CHOICE EXPERIMENTS

    3.4.1 Experimental Design

    3.4.2 Experimental Procedures

    3.4.3 Recalculation of Input Models

    3.4.4 Predicted and Observed Choice Strategies

    3.4.5 Calculation of Perceived Costs

    3.4.6 Conclusions

3.   MODELS OF HUMAN-COMPUTER INTERACTION

Mario C. Grignetti
Duncan C. Miller

3.1   INTRODUCTION

In this annual technical report we describe the work
performed and the results obtained from two series of
man-computer-interaction experiments. These experi-
ments were designed to test the feasibility of methods
to improve the overall efficiency (computer and users)
of a time-sharing system, by artificially manipulating
the computer's response characteristics so as to influ-
ence the users' choice of interaction commands.

The body of the report is organized in three subsections.

In subsection 3.2 we state the purpose of the experiments
and present a succinct overview of our aims and methods.
We include, for completeness, aspects reported in detail
previously.

Subsection 3.3 describes the results of the first series
of experiments,and subsection 3.4 presents and discusses
in detail the results of the second series of experiments.

A paper entitled "Modifying Computer Response Character-
istics to Influence Command Choice" to be published in
the Proceedings of the IEE Conference on Man-Computer
Interaction, 2-4 September, 1970, summarizes the results
and conclusions reported in this document. This paper
will be included as part of our next semi-annual report.

3.2   GENERAL OVERVIEW

We are concerned with situations involving user-computer
interactions in a time-sharing system environment and
the relationship between user behavior and overall system
performance. Our task is to find ways to influence user
behavior so that system performance is improved.

3.2.1   Definition of Approach

In a typical situation, users can choose among several
alternative sets of commands which will accomplish a
certain result. All other things being equal, they will
choose a set of commands that is simple to figure out
over a complicated one, one that requires a short time
to type in over one that requires longer to type in, a
rapidly executed command over a time-consuming one, or,
if the difference is apparent to the users, a "cheap"
command over an "expensive" one.

135

The ability of a user to make an intelligent choice (i.e.
one that will accomplish his goals in a manner that is
satisfactory to him) hinges on several factors, among
them:

a) a thorough understanding of the system
   dynamics, so that he may be able to
   predict system response with a given
   flow of resource demands.
b) knowledge of the total load imposed
   on the computer by all users.

With complete communication among users and thorough
understanding of computer system dynamics, user behavior
can usually be adjusted by direct interpersonal co-
ordination. This situation prevails only in closely
knit research computer installations involving a few
users who know each other very well. In large, remote
access TSS's this is virtually impossible. Hence, the
TSS itself must provide the means to coordinate and
regulate user behavior.

One way to do this is by incorporating into the TSS the
capability of providing incentives to lead individual
users to adopt behavior that, although it may seem against
their best interests at first sight, will result in
their greatest satisfaction in the long run, and that
will improve overall system performance.

What might these incentives be? One system character-
istic that affects user behavior is the apparent system
response time. Presume that (as is generally the case)
a user may choose among several different series of
commands to achieve a certain goal. Some series of
commands will require a small expenditure of the comp-
uter's resources in executing them, but will require
careful planning. Others may require a greater expen-
diture of the computer's resources, but demand much
less planning. Which will he choose? His choice will
depend on the tradeoff he perceives between his
planning effort and the system response time. If the
system is lightly loaded and responds quickly to any
series of commands, he will probably choose the series
that minimizes his planning effort. If, however, the
system responds sufficiently faster to a well-planned
series of commands, then he will find the extra planning
effort worthwhile. If a system designer could predict
the user's choices, then he might attempt to discourage
operations which result in inefficient system per-
formance by placing an artificial time penalty on such
operations.

We suggest, however, that there are other ways to affect
a user's behavior without inflicting artificial time
penalties upon him. Some approximation to the real "cost"
of a command (in terms of its load on system resources)

could be made explicitly available to him, and he could
be encouraged to balance the "cost" of various commands
against the planning and execution times that they
require. For example, a user might be allotted a certain
number of cost units as he begins a session. He could
receive high priority service until he used up the
allotted cost units; then he would receive some lower
priority service. This would encourage him to weigh
carefully the costs of his commands against the times
consumed. Before pursuing these ideas any further, we
must answer two fundamental questions:

Would users choose different commands when cost con-
siderations are explicitly presented to them than they
would without such information? Would their behavior
change, if at all, in a predictable way?

3.2.2 Methodology

In order to answer the questions just posed, it was
necessary to design an experiment in which computer
users would perform a task with the following charac-
teristics:

1) The task must be such that it can be accomplished
    in several different ways, by choosing commands
    that involve trade-offs between user's time and
    cost.
2) The cost must approximate the actual expenditure
    of computer resources.
3) Sufficient information must be fed back to the
    user so that he can make intelligent command
    choices.
4) The task must be easily generated, so that
    variations of it can be produced with a given

138

index of difficulty.

5) The computer response characteristics must be
controllable by the experimenter.

6) The experimental conditions must be such that
subjects can be motivated to optimize their
level of performance.

7) The experiment must be representative of some
kind of user-computer interaction which is
typical of users of a time-sharing system.

A simple task that satisfies these requirements involves
the correction of a series of errors in a symbolic file
by means of an editing program that, after each inter-
action, feeds back cost and time information to the
user.

The text used for our experiments consisted of an unlimited
number of pages containing exactly 100 one-line sentences.
The sentences are of the fixed syntax type (article,
adjective, noun, adverb, verb, article, adjective, noun)
and were generated by drawing at random from a pool of
stored adjectives, nouns, etc. An example is:

THE HIRSUTE PORCUPINE ANGRILY PUNTED A CRUMPLED SURFBOARD.

Errors were then generated on each of the pages with
particular care to keep constant the degree of difficulty
of the task and to maintain good ensemble properties.
Five parameters characterized the errors, namely: sentence
length (from 30 to 65 characters), error position in the
sentence (from the 5th to the 15th or from the 35th to
50th character), minimum number of characters that
specify uniquely the position of the error, number of
characters to be deleted, and number of characters to
be inserted. Errors were made to appear early or late

in the sentence, to involve from one to three characters
to specify its position, and to require the deletion
and/or insertion of from zero to two characters. A
total of 48 errors per page were thus created, invol-
ving a balanced blend of error parameters. An error-
generation program was implemented that, given a page
of text, figured out how to introduce all 48 error
types and produced a listing of the corrupted text with
errors clearly labeled and ready to be turned over to
the subjects. In this way, a practically endless sup-
ply of basic material for experimental runs was obtained.
A sample is included.

To edit the text, we wrote a program (MINITECO) that
allows the subjects to correct those errors by means of
four different commands:

1) The KILL command essentially erases the sentence
    chosen by the subject and allows the subject to
    retype the sentence (and, hopefully, its correct
    version) in its entirety.
2) The DELETE and INSERT command requires the subject
    to count manually the number of characters up to
    the error, and then to input this number, followed
    by the number of characters to be deleted (if any)
    and the characters to be inserted (if any).
3) The SEARCH command allows the subject to give a
    character string to specify the position of the
    error in the sentence, followed again by the
    number of characters to be deleted and the string
    of characters to be inserted.
4) Finally, the REPLACE command is of the form
    "replace 'old string' with 'new string'".

MINITECO makes sure that the subject's command fixes the
sentence correctly and without overspecifications and

140

                      TI
0 A DETECTIVE GLEEFULLY PICKLED THE SPOKY HELICOPTER.

                      JA
1 THE POMPOUS BUSBOY POWDERED A GRIMY TVCKAL.

2 A WEALTHY DETECTIVE DECEPTIVELY VARNISHED A MYSTERIOUS WATERMELON.

      A
3 A HISHAY BURGLAR SHYLY PICKLED A BLOATED LIZARD.

4 THE WAITRESS INDIGNANTLY DEVOURED THE SHAGGY SOW.

                                  R
5 THE BOOKISH WAITRESS FEARFULLY MANGLED A FOXAGRANT HUBCAP.

6 THE HATTER PUNCTURED A MYSTERIOUS TUBA.

7 THE WEALTHY GOURMET TWIRLED A SLIPPERY TUBA.

8 THE SKYCAP MASSAGED THE SPEEDY TROWEL.

9 A CANNY POLITICIAN SLUGGISHLY IGNORED THE BRIEFCASE.

          U
10 A WEALTHY GO WRMET PICKLED THE BRIEFCASE.

11 THE POMPOUS GURU PUNCTURED A FRISKY SLOTH.

           O
12 A STUBBORN GNDOLIER PICKLED THE MAGNETIC STATUE.

13 THE POLITICIAN SLUGGISHLY MELTED A SPEEDY HELICOPTER.

14 THE FELON RUTHLESSLY VARNISHED THE GRIMY SOW.

15 A WAITRESS ABSENTLY DEVOURED A MAGICAL HUBCAP.

                        TE
16 A LISTLESS CABBIE TWIRLED THE MYS RIOUS TUBA.

17 A STUBBORN DETECTIVE GLEEFULLY POWDERED THE SPEEDY SPATULA.

Sample of text to be edited

```
03/05/70 1707:28
OUTPUT FILE: /3:5CA1/.
SUBJECT NAME: CAROL
EXCTIME  3

COSTS=  0    0    0    0

REWRDS=  5    5    5    5
TIME ALLOWED=  1000
PAGE NUMBER 8
*0'48C2DIM'       ( 52   48    3    2    1   )
(R 5  C 0  V 5   T   15.6  TV 5   TT   15.6  )RT    7.6
1'32CILE'         ( 54   32    2    0    2   )
(R 5  C 0  V 5   T   15.0  TV 10  TT   30.6  )
3'13C2DIE'        ( 47   13    2    2    1   )
(R 5  C 0  V 5   T   10.5  TV 15  TT   41.1  )
7'50C1DIZ'        ( 53   50    2    1    1   )
(R 5  C 0  V 5   T   21.9  TV 20  TT   63.0  )
8'35CIU'          ( 37   35    2    0    1   )
(R 5  C 0  V 5   T   14.6  TV 25  TT   77.6  )
10'11C1D          ( 52   11    3    1    0   )
(R 5  C 0  V 5   T    8.6  TV 30  TT   86.2  )
14'7C1DIU'        ( 40    7    1    1    1   )
(R 5  C 0  V 5   T   10.3  TV 35  TT   96.5  )
17'7C1DIR'        ( 63    7    3    1    1   )
(R 5  C 0  V 5   T   16.2  TV 40  TT  112.7  )
18'5CIB'          ( 26    5    1    0    1   )
(R 5  C 0  V 5   T   10.5  TV 45  TT  123.1  )
19'49CII'         ( 53   49    1    0    1   )
(R 5  C 0  V 5   T   18.5  TV 50  TT  141.7  )
21'17C2D          ( 58   17    1    2    0   )
(R 5  C 0  V 5   T   10.2  TV 55  TT  151.9  )
22'16C2DIL '      ( 47   16    1    2    2   )
(R 5  C 0  V 5   T   11.7  TV 60  TT  163.6  )
26'13CIL'         ( 60   13    3    0    1   )
(R 5  C 0  V 5   T   15.6  TV 65  TT  179.2  )
27'8CINN'         ( 46    8    1    0    2   )
(R 5  C 0  V 5   T    9.7  TV 70  TT  188.9  )
28'11CITL'        ( 47   11    2    0    2   )
(R 5  C 0  V 5   T    9.6  TV 75  TT  198.5  )
34'33C2DIMI'      ( 46   33    2    2    2   )
(R 5  C 0  V 5   T   15.2  TV 80  TT  213.7  )
35'7C1D           ( 55    7    2    1    0   )
(R 5  C 0  V 5   T    6.7  TV 85  TT  220.4  )
36'13C2DID'       ( 54   13    1    2    1   )
(R 5  C 0  V 5   T   18.2  TV 90  TT  238.6  )
38'35C2DIRE'      ( 37   35    3    2    2   )
(R 5  C 0  V 5   T   17.2  TV 95  TT  255.8  )
40'15C1DIEL'      ( 48   15    1    1    2   )
(R 5  C 0  V 5   T   11.1  TV 100 TT  266.9  )
44'31C1D          ( 42   31    2    1    0   )
```

Initial Segment of a data file produced by MINITECO

feeds back to the subject information on cost incurred
and time elapsed to input and perform the command. The
subject can not input the next command until MINITECO
allows him to; in this way we were able to simulate, by
introducing artificial time delays, a wide variety of
computer response times.

MINITECO also performs the data-gathering tasks necessary
to analyze the results of the experiments. A portion of
a typical data file is also included. The format of these
data is as follows:

Two lines of printed output are produced for every attempt
to fix an error.

The first line contains

1) Sentence number, terminated by '.
2) Command string.
3) The five error parameters (length, position,
   minimum number of characters to specify er-
   ror position, number of characters to delete,
   number of characters to insert).

The second line contains

1) Reward
2) Cost
3) Value = Reward - Cost
4) Time to input the command (includes computer
   response time, EXCTIME)
5) Accumulated value
6) Accumulated input time
7) Computer response time, if greater than nominal.

3.3 NO-CHOICE EXPERIMENTS

Our first series of experiments was aimed at constructing
input models that would allow us to predict how much
time it would take a subject to input a given command to
fix a sentence with given error parameters. This step
is a crucial one, because if it turned out that a
subjects' behavior could not be accounted for in a
reasonably predictable way even for such a simple and
restricted task, there would be no reason to believe
that they would behave predictably in a more complex
situation.

To this end we conducted a series of experiments in which
subjects were required to correct errors using only one
command. We ran our subjects on each of the 4 commands
and for 3 different computer response times (3, 9, and
27 seconds).

3.3.1 Overview

Our results generally confirmed that input model con-
struction was possible, so that indeed when the computer
response time was short (3 secs), we observed a linear
relationship between the time to input a KILL command
and the sentence length, and between the time to input a
DELETE/INSERT command and the error position.

A surprising result was the absence of significant cor-
relation between the time to input a SEARCH command and
the minimum number of characters to specify the error's
position. We had expected that the longer the string a
subject would have to search for scanning through the
sentence in order to make sure that it would uniquely

144

specify (but not overspecify) the position of the error,
the longer it would take to input the command. It ap-
pears that subjects treat search strings as units, reg-
ardless of the number of characters in them. Another
characteristic feature of SEARCH commands (again best
observable under short response time conditions) was
the small correlation between input time and error pos-
ition.

For the REPLACE command, the most salient result was the
absence of significant correlation between input time and
any of the error parameters. There was slight evidence
in favor of correlation of input time with error pos-
ition and with number of characters required to specify
the command (a linear combination of error parameters)
but not to any significant level.

3.3.2 Detailed Description and Results

Three expert technical typists, experienced in preparing
and editing technical reports on-line in a time-sharing
system, were selected as subjects.* They were offered a
reward of 5¢ for each command that attempted to correct
an error. If the attempt was successful and the command
was not overspecified (for example, by giving more than
the minimum number of characters to specify a SEARCH),
no cost was deducted and the reward accrued to the
subjects as incentive pay. If an overspecification
existed, if the command was syntactically illegal, or
if the attempt was not successful, the reward was nul-
lified by charging the subject a cost of 5¢.

The subjects were given a page of error text at the
beginning of each run and were instructed to fix as
many errors they could with a given command during
the allotted period of time. This period was cal-
culated so that they generally had ample time to fin-
ish a whole page. They were authorized to start
over after they had fixed the last error. The data
from the repeated fixes was stored but was not con-
sidered for analysis. The subjects were thoroughly
trained until their earnings per run stabilized.
Data from a total of 158 runs, mostly 1000 secs in dur-
ation, were obtained and recorded on magnetic tape.
The last 3 runs of each subject and each command were
actually used for analysis purposes.

In the remainder of this subsection we present results
for each of the 4 commands, when the computer response
time was adjusted to be 3 secs. Less detailed results
are given for the other two response times used, and
only when they cannot be inferred directly from the
results for 3 secs.

3.3.2.1 KILL Command

As expected, there was strong correlation between the time
to input a KILL command and the number of characters in
the sentence. Best linear fits performed over ensembles
of runs gave the results contained in Table 1.

TABLE I.

BEST LINEAR FITS FOR KILL COMMAND

Subject Name	Response Time (sec)	Intercept with L=0 (K_1)	Value for L=30	Slope (K_2)	Correlation Coefficient
CAROL	3	6.3	15.6	.31	.67
CAROL	9	12.3	20.7	.28	.70
SARAH	3	6.7	13.9	.24	.60
SARAH	9	13.6	19.9	.21	.73
SUE	3	0.6	13.8	.44	.75
SUE	9	12.5	24.7	.41	.61
SUE(-1 run)	9	7.3	22.0	.49	.72

Plots for typical runs are given in Figs. 1 and 2.
Several comments are in order at this point.

a) Interpreting slope as typing speed, we see that
   our subjects can be ranked in the order Sarah,
   Carol, Sue. Notice how the typing speed in-
   creases slightly when going from 3 secs to
   9 secs response time. We attribute this ef-
   fect to the subjects having time to memorize
   at least part of the sentence before they
   are able to start typing it in.

147
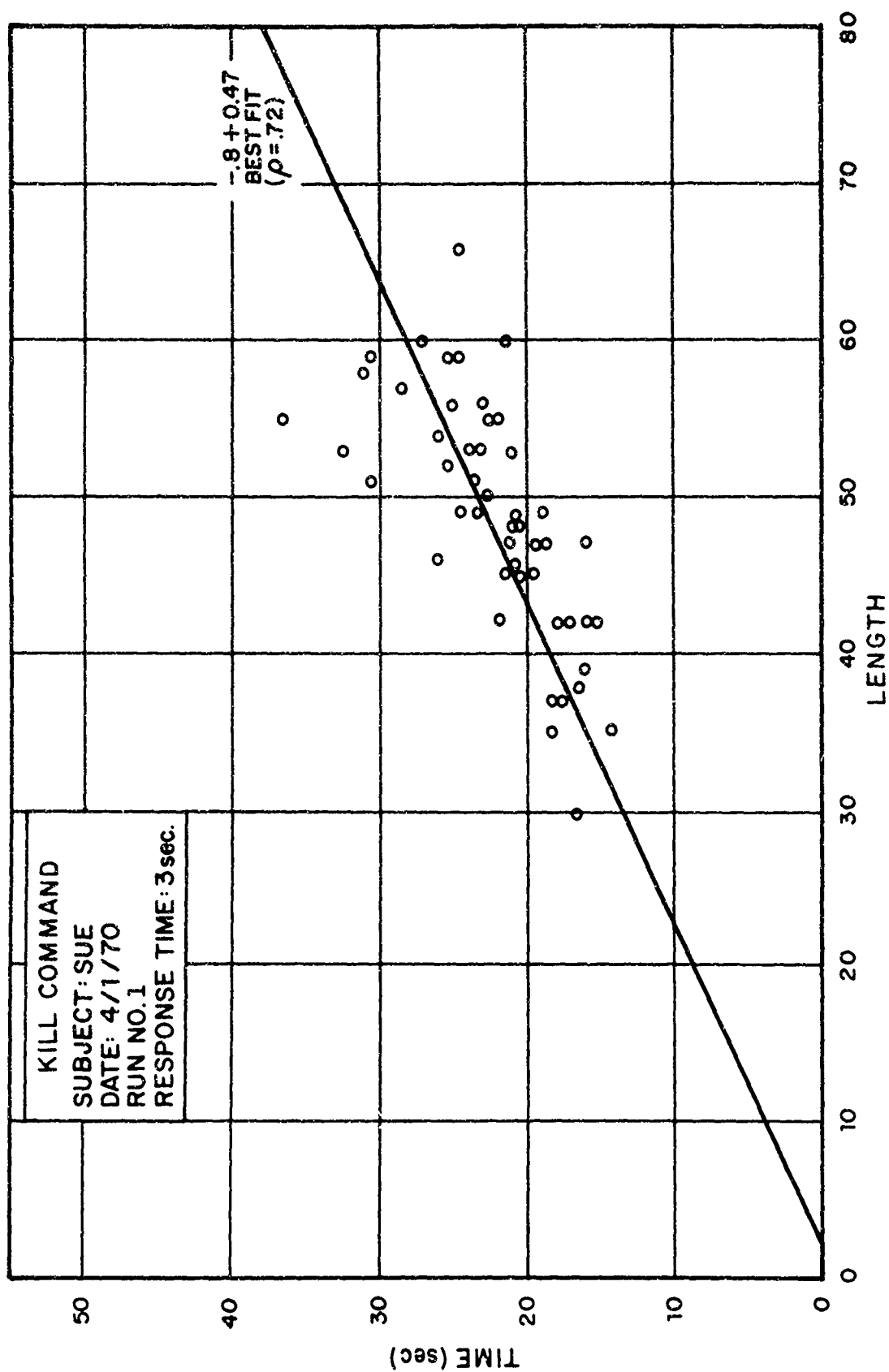
Fig. 1 Time Required for KILL Command, as a Function of Sentence Length. Subject: Carol
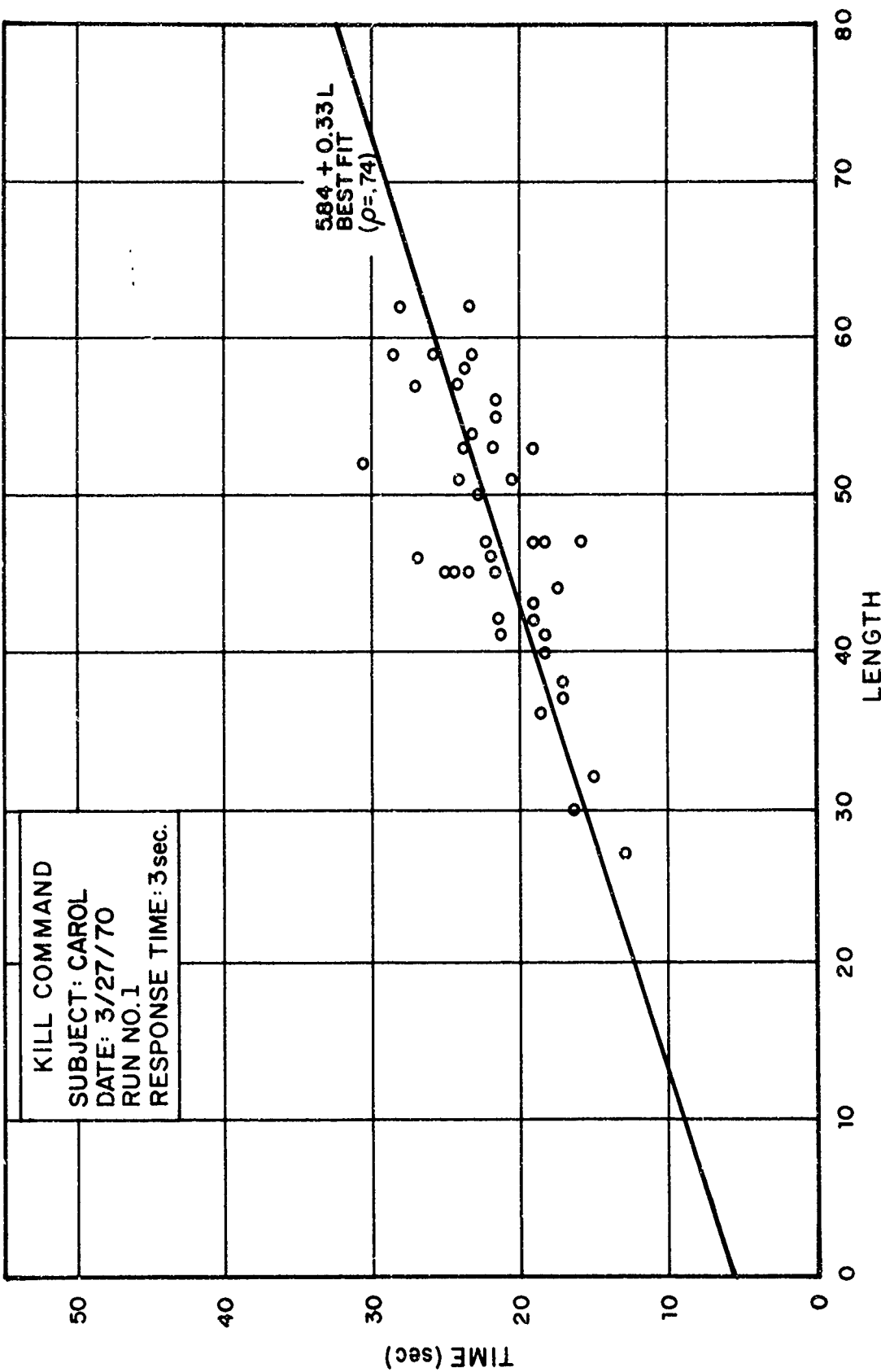
Fig. 2 Time Required for KILL Command, as a Function of Sentence Length. Subject: Sue

b) The best linear fits for Carol and Sarah
are very similar to each other. The
intercepts both change by roughly 6 secs
when the computer response time is
increased from 3 secs to 9 secs. The
best linear fit for Sue, however is
markedly different: the intercepts both
increase by roughly 12 seconds when going
from 3 secs to 9 secs response time, and
the value of the intercept with L=0 is
an impossibly low 0.6 secs when the
response time is 3 secs. One way to
explain the inter-subject intercept
difference is by realizing that sent-
ence lengths of less than 30 characters
are very rare. Therefore, comparing
results by extrapolation to a sentence
length of $\emptyset$ is not justifiable when
large differences in slope are observed.
Comparison of intercepts with L=30 (i.e.,
the times required to input a 30-charac-
ter sentence) gives more uniform results.

The intra-subject difference of 12 seconds for Sue is more
difficult to explain. Closer examination of the data re-
veals that the ensemble values for 9 secs response time
may have been affected considerably by an atypical run
with large scattering of datum points. The last row in
Table 1 gives the results obtained when this run is
eliminated.

150

3.3.2.2 DELETE/INSERT Command

Correlations of input time with error position and with number of characters to delete and insert were anticipated in this case. However, since the importance of the former vastly overshadows the latter, we shall restrict ourselves to reporting results for error position only.

Best linear fits performed over ensembles of runs gave the results contained in Table II. A typical run is reproduced in Figure 3.

TABLE II
BEST LINEAR FITS FOR DELETE/INSERT COMMAND

Subject Name	Response Time (secs)	Intercept with P=0 (D_1)	Value for P=10	Slope (D_2)	Correlation Coefficient
CAROL	3	8.5	10.7	.22	.85
SARAH	3	10.6	12.5	.19	.56
SUE	3	11.9	15.6	.37	.76

Interpreting slope as counting speed, the subjects rank in the same order as before, namely, Sarah, Carol, Sue.

DELETE/INSERT data were also analyzed for computer response times of 9 secs and 27 secs. The linear relationship observed for a response time of 3 secs is a consequence of the fact that very little planning for the next command can be done in that period of time. When the response time is 27 seconds, virtually all planning can take place while the computer is "working", so we do not expect any correlation between input time and error position. This is indeed what happens, as can b seen in Figure 5. When

151

the response time is 9 secs, we observe a mixture of the
previous modes: if the error occurs late in the sentence
there is not enough time to count up to it while the
computer is "working" and a linear dependence in error
is observed; while if the errors occur early in the sentence,
the subject has finished planning the command when the
computer is ready for him to input the command and there-
fore no correlation of input time with error position
is observed. An example of such a mode of behavior is
given in Figure 4.
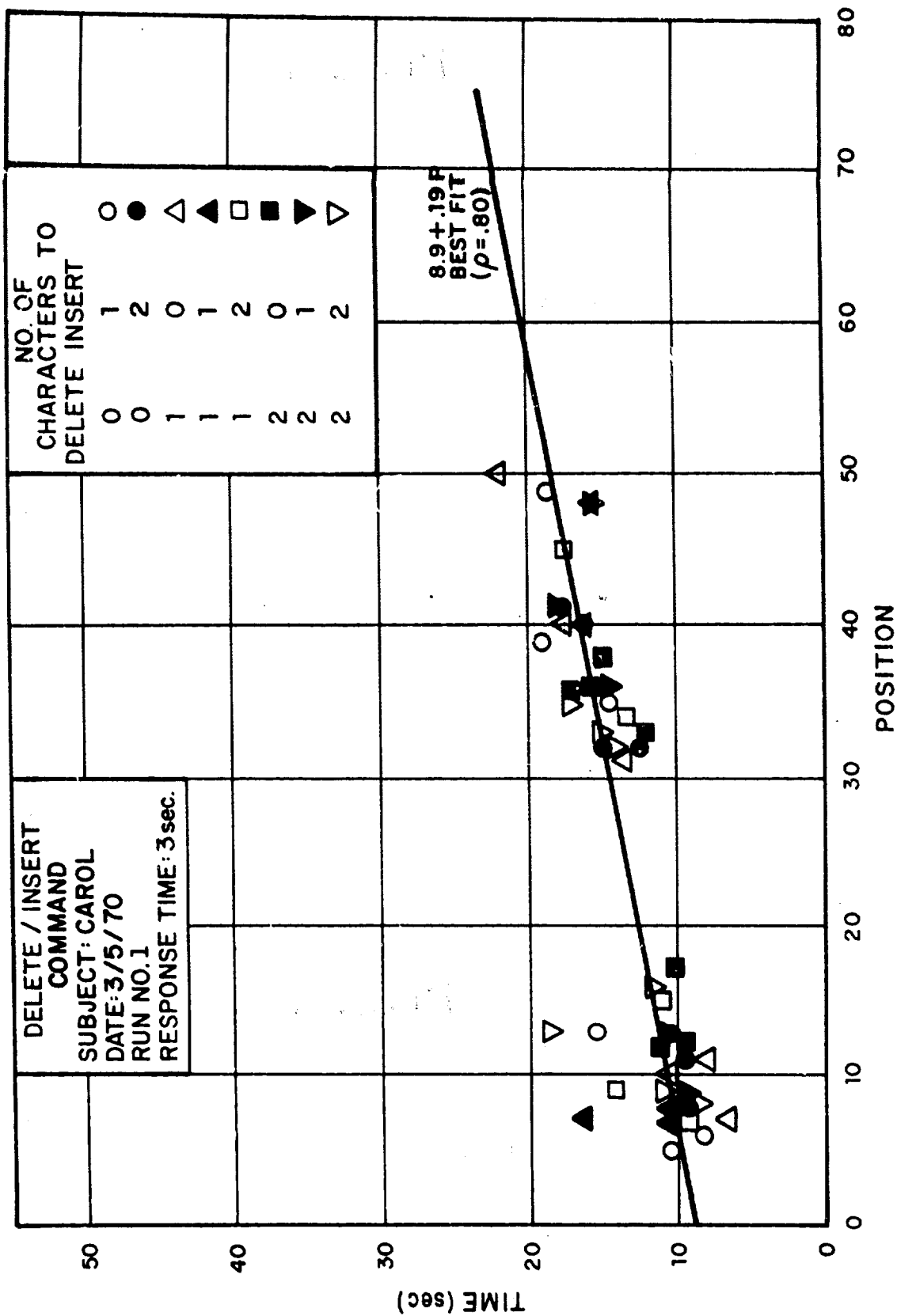
Fig. 3   Time Required for DELETE/INSERT Command, as a Function of Error Position, with Computer Response Time of 3 sec.
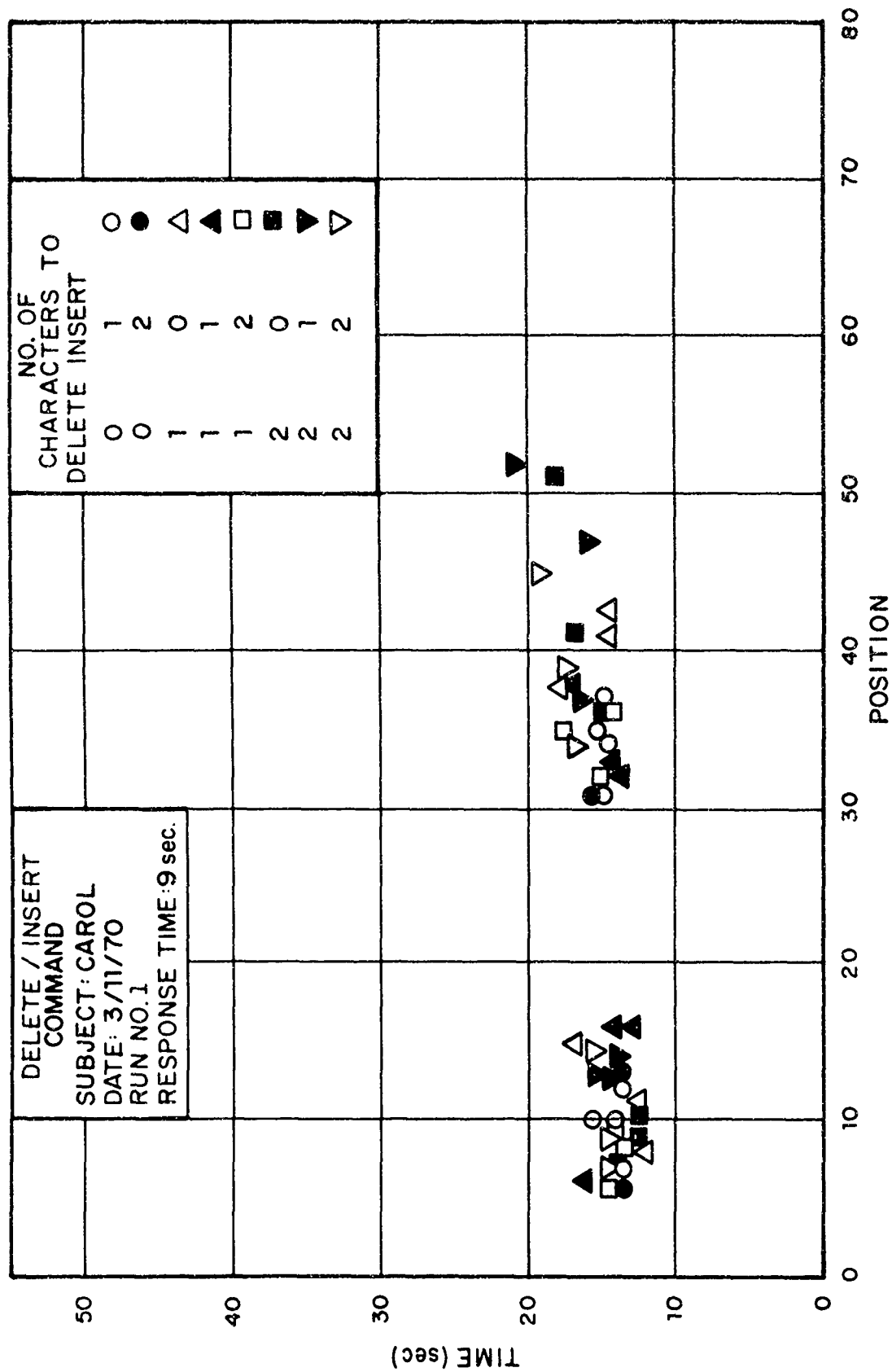
Fig. 4   Time Required for DELETE/INSERT Command, as a Function of Error Position, with Computer Response Time of 9 sec.
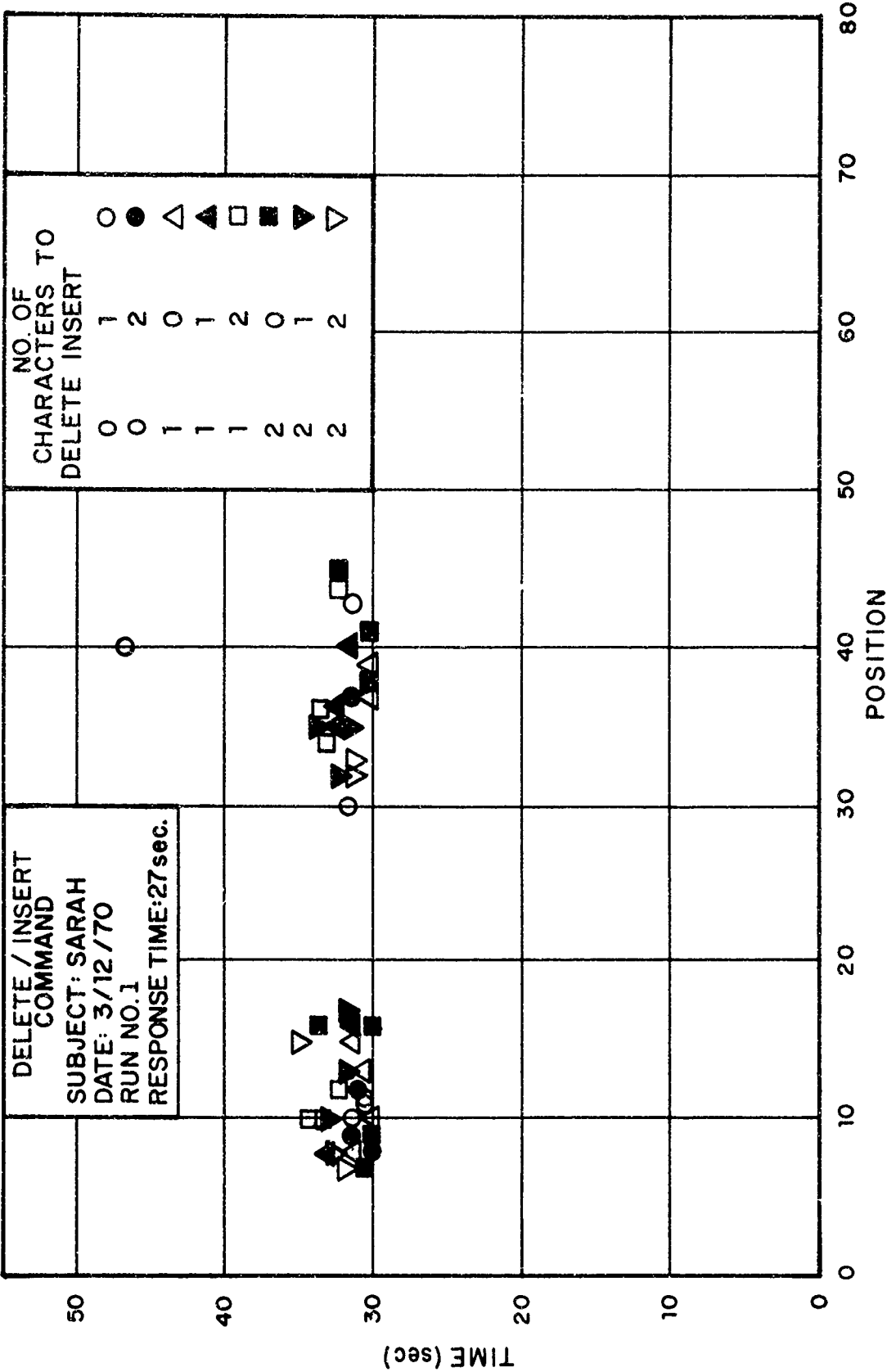
Fig. 5   Time Required for DELETE/INSERT Command, as a Function of Error Position, with Computer Response Time of 27 sec.

3.3.2.3 SEARCH Command

This command, essentially similar to the REPLACE command, was included in MINITECO with the intention of making explicit the effect of the minimum number of characters to specify an error's position on input time. We figured that the longer the character string a subject had to type to specify uniquely the error position, the longer it would take him to think up the command. Our results proved very clearly, however, that no significant such correlation exists. A small correlation was observed between input time and error position. Results are given in TABLE III and a typical plot appears in Fig. 6.

TABLE III

BEST LINEAR FITS FOR SEARCH COMMAND

Subject Name	Intercept	Slope	Correlation Coefficient	Average Input Time (S_1)	Standard Dev.
CAROL	10.8	.06	.27	12.1	3.0
SARAH	12.1	.05	.22	13.2	3.3
SUE	13.8	.08	.27	15.6	4.0
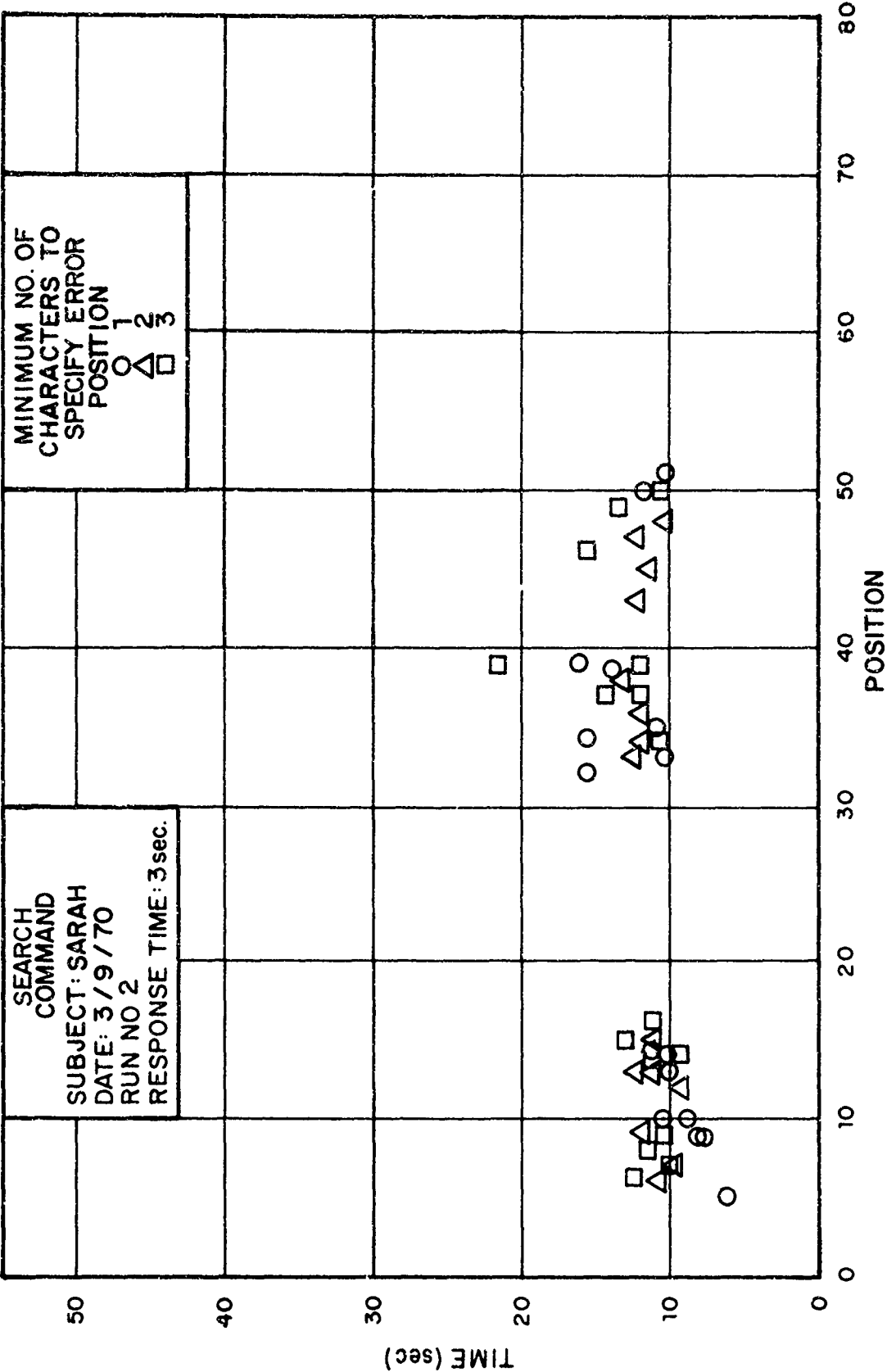
Fig. 6 Time Required for SEARCH Command, as a Function of Error Position

3.3.2.4   REPLACE Command

A number of significant correlations between input time and
various combinations of error parameters were expected for
this command. We expected, for example, to see the input time
increase as the number of characters to specify the position
of the error increased, as the number of characters to delete or
insert increased, or as the error position increased. Analysis
of the results revealed, however, that in spite of some
evidence in favor of such correlations, they were so small
that it was not worthwhile to consider them. The results
for the case of input time vs. error position reproduced
in Table III illustrate very well this point. A typical
plot is represented in Fig. 7.

TABLE IV   BEST LINEAR FITS FOR REPLACE COMMAND

Subject Name	Intercept	Slope	Correlation Coefficient	Average Input Time (R_1)	Standard Dev.
CAROL	11.3	0	0	11.3	2.9
SARAH	11.1	.06	.21	12.5	3.8
SUE	12.8	.05	.19	14.2	4.2

Considering that the average early error occurs around the 10th
character position, and the average late error occurs around
the 40th character position, the difference in input time
would be at most 1.8 seconds, which, given the sample
variances observed, can not be considered significant.

In the interest of simplicity and effectiveness, it is best to
adopt a constant time equal to the average ensemble value,
reproduced in Table IV, as a model for the time to input a
REPLACE command.

158
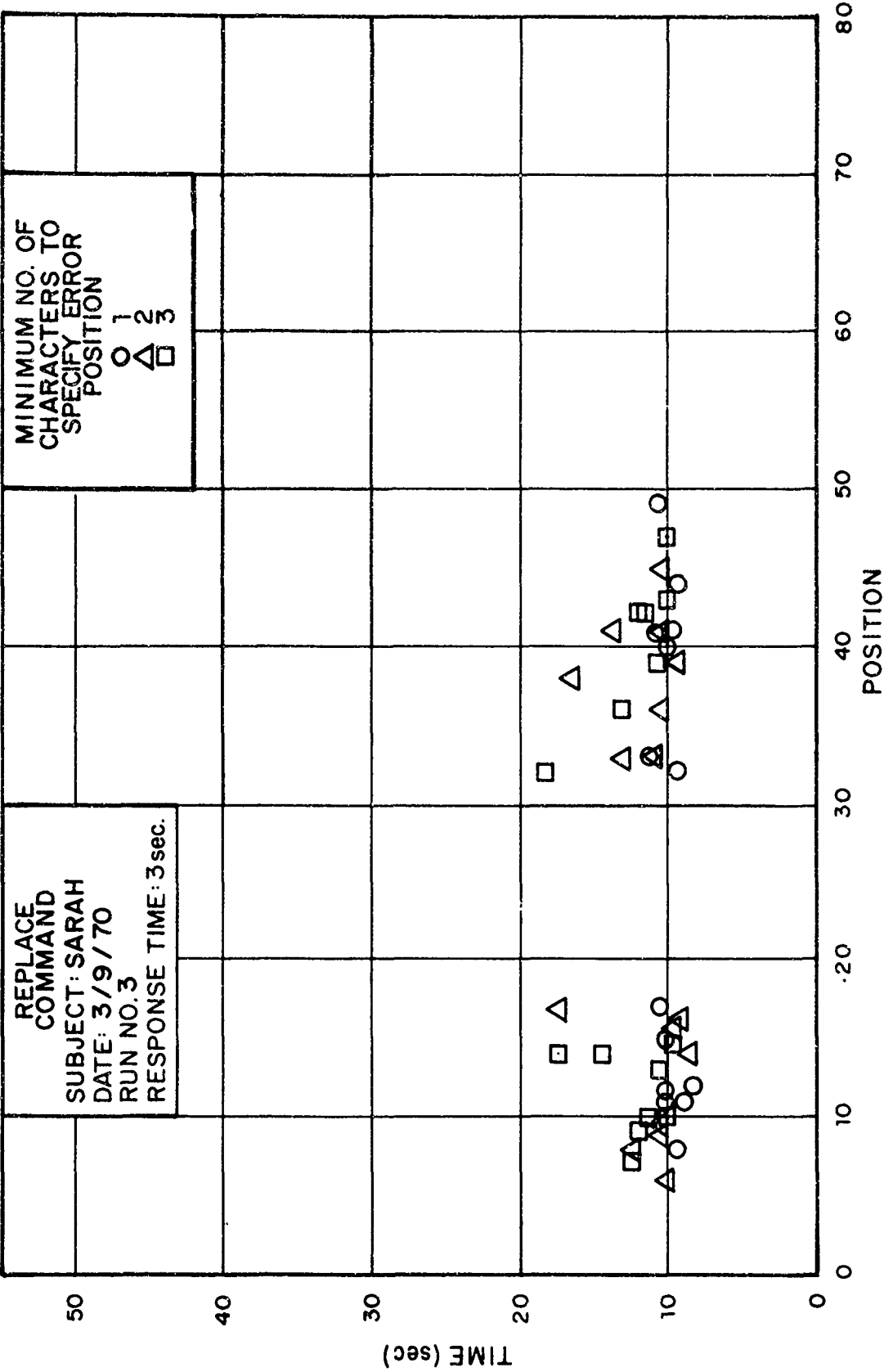
Fig. 7 Time Required for REPLACE Command, as a Function of Error Position

3.3.3 Conclusions

Our conclusions from this first series of experiments were the
following ones:

1) For the shortest response time (3 seconds) the time
   to input a command could be modeled as a linear function
   of either sentence length, L, or error position, P.
   The models were:

   KILL command) $T_k = K_1 + K_2 * L$

   DELETE/INSERT command) $T_d = D_1 + D_2 * P$

   SEARCH command) $T_s = S_1$

   REPLACE command) $T_r = R_1$

   Values for these coefficients are given in

   Subsection 3.3.2.

2) For the longest response time (27 seconds) the time to
   input a command reflects only the typing time, since all
   the planning could take place while the subject was
   waiting for the computer to allow him to input the next
   command. Consequently, the time to input DELETE/INSERT,
   SEARCH, or REPLACE commands was essentially constant.

3) For the intermediate computer response time (9 seconds)
   the input time exhibited characteristics common to the
   two previous modes of operation. For example, for the
   DELETE/INSERT command, when the error occurred late in
   the sentence (so that it would take the subject longer
   than 9 seconds to count characters up to the position of
   the error) there was significant correlation between input
   time and error position; when the error occurred early in
   the sentence, the input time remained essentially constant.

It is apparent from these results that if subjects were given
a free choice of commands to correct an error and were constrained

160

only to be time efficient, they would never
use the KILL command since it takes the longest. This
conclusion becomes even more clear when other factors are
considered, such as the reluctance to choose a command that
requires typing many more characters than any of the other
available commands.

3.4 CHOICE EXPERIMENTS

Our second series of experiments was designed to test whether
or not users could be effectively and predictably motivated
to change their choice of commands under the incentive of cost
differences among the available commands.

3.4.1 Experimental Design

In constructing an experimental system in which our subjects
could be motivated to make cost-vs.-time tradeoff decisions,
several requirements had to be met:
1) The experimental conditions had to result in significant
    differences in the costs and times required to correct a
    given error with each alternative command type, and
    hence in the resulting pay rates.

    This requirement led us to choose a constant computer
    response time of 3 seconds, since at longer response
    times the planning times required by different command
    types lose their effect.

2) The pay rate differences between alternative command types
    had to change significantly with the different error
    parameters of various sentences.

161

This requirement is met by KILL (where pay rate is a
function of sentence length) and DELETE/INSERT (where
pay rate is a function of error position); the pay rates
for these commands will differ from each other and from
that of REPLACE for various sentences of different
lengths and error positions.

This same requirement led us to eliminate the SEARCH
command as one of the choices available to the subjects.
The variation of input times for SEARCH with error
position is not significant enough to change its pay
rate much. Therefore, regardless of the costs assigned
to SEARCH and REPLACE, the pay rates corresponding to
these commands would tend to differ by the same amount.

3) The costs assigned to the various command types must be
    such that each command type will have the highest pay
    rate for some combination of sentence length and error
    position. In other words, no command type should
    always be best or never be best for a given set of
    error sentences.

    The third requirement posed something of a problem.
    Using the input models developed in the no-choice
    experiments, we predicted that a reward of 10¢ for
    each error corrected and costs of 1¢, 5¢, and 6¢ for
    KILL, DELETE/INSERT, and REPLACE would result in each
    command type being best approximately one-third of the
    time. However, the no-choice input models might not
    be valid for the choice experiment. In the no-choice
    experiments, the subjects knew exactly which command
    type they were going to use for their next command. In
    the choice experiments, they would have to consider
    alternative commands. Any time spent weighing alternatives

would tend to increase the time spent on whatever command
they ultimately chose. This might change the input models
enough to render our predictions invalid. Clearly, new
input models for each command would have to be extracted
from the choice experiment data and compared with the
no-choice models.

3.4.2 Experimental Procedures

Our three subjects were provided pages of error text sim-
ilar to those that they had used in the no-choice exper-
iments. Each experimental run was limited to 1000 seconds,
during which time the subject could correct errors (in
sequence) using any of the three allowable commands. If
a subject finished the 48 error sentences in a set of
error text before time ran out, she was allowed to continue
correcting old error sentences. Only the data for fresh
error text, which she had never seen before, were retained
for analysis, however. Two or three 1000-second runs
were conducted per session. Each subject made a total of
approximately 30 runs.

At the beginning of the experiments, it was pointed out to
the subjects that they had to weigh carefully the cost
against the time consumed for each command type for each
sentence. They were told that each command type would
be best for some sentences but not for others. No
specific methods were suggested for determining which
command type was best for a given sentence – it was simply
suggested that they pay careful attention to the cost and
time information provided them by MINITECO.

The subjects were paid one-half of the total value indi-
cated at the end of each run. As they evolved their choice

163

strategies, their actual earnings increased from approx-
imately $1.25 per 1000 seconds for the first run to
approximately $2.25 by the fifteenth run. By the thirtieth
run, they were earning approximately $2.50 per 1000
seconds.

3.4.3 Recalculation of Input Models

Data for the final 12 to 15 runs for each subject were
selected for analysis*. Data points representing erroneous
commands or input times greater than 30 seconds (which
resulted from a subject's being interrupted or distracted)
were discarded**, and the remainder segregated by the command
type used. For each command type, input models were
recalculated in the same manner as for the no-choice data.
The results are shown in Table V along with those obtained
in the no-choice experiments with a 3-second system res-
ponse time.

---

*We are grateful to Daniel Kalikow for producing a program
that reduced the data generated by MINITECO to an easily
analyzable form,
** Approximately 2% of the data points were discarded for
these reasons.

TABLE V
BEST LINEAR FIT MODELS

	NO-CHOICE DATA			CHOICE DATA		
	intercept	slope	corr.	intercept	slope	corr.
KILL						
CAROL	6.3	.31	.67	5.8	.26	.44
SARAH	6.7	.24	.60	7.1	.17	.33
SUE	0.6	.44	.75	6.2	.25	.42
DELETE/INSERT						
CAROL	8.5	.22	.85	6.5	.23	.32
SARAH	10.6	.19	.56	6.9	.24	.28
SUE	11.9	.37	.76	8.7	.16	.10
	mean	std. dev.		mean	std. dev.	
REPLACE						
CAROL	11.3	2.9		11.0	3.0	
SARAH	12.5	3.8		10.0	3.0	
SUE	14.2	4.2		9.2	2.7	

As discussed in Section 3.4.1, we expected that the times
required to execute each command would, if anything, increase
when the necessity for choosing between commands was intro-
duced. An examination of Table V shows that these ecpect-
ations were not confirmed: in many cases, the times
required are substantially lower. There are probably
several reasons for these results:

1) The no-choice experiments were run with computer
   response times of 3, 9, and 27 seconds. A response
   time of 3 seconds, which was used exclusively in
   the choice experiments, requires considerable
   alertness from the subjects and allows no time

for resting between commands. Evidently, as
the subjects accumulated additional experience
with the 3 second response time, they were able
to improve their general level of efficiency.

2) The subjects found the choice experiments more
   challenging than the no-choice experiments,
   and may have been better motivated to perform
   well.

3) The subjects tended to use the KILL command
   primarily for short sentences, and DELETE/INSERT
   command primarily for errors lying early in a
   sentence. Therefore, the population of data
   points from which the best linear fit models
   were calculated was different from that of the
   no-choice experiments. Perhaps the subjects
   were able to develop ways of retyping short
   sentences and correcting early errors that were
   more efficient.

3.4.4 Predicted and Observed Choice Strategies

Before using the recalculated input models to check the
optimality of the subjects' strategies, let us examine the
data to see what strategies they adopted.

Figures 8, 9, and 10 show the commands chosen by each subject
during the final 12 to 15 runs as a function of sentence
length and error position. For example, Fig. 8 shows that
subject Carol encountered 7 occurrences of an error begin-
ning at the 9th to 11th character of a sentence 36 to 37
characters in length; 4 times she used the KILL command,
and 3 times she used DELETE/INSERT.

Figure 8 shows that Carol adopted a highly consistent
strategy. If a sentence was shorter than 40 characters,

166

Figure 8 — Data grid (Subject: Carol). Ordinate = error position; Abscissa = sentence length. Cell values are counts followed by command letter (K, R, or D).

Err	26/27	28/29	30/31	32/33	34/35	36/37	38/39	40/41	42/43	44/45	46/47	48/49	50/51	52/53	54/55	56/57	58/59	60/61	62/63	64/65	66/67
51														3R	4R	1R					
48												2R	4R	3R	3R	2R	1R	1R	2R		
45											3R	5R	6R	2R	10R	5R		1R			
44							1K	1K													
42									7R	6R	5R	2R	5R	7R	2R	3R	1R				
41							3K	4K													
39									5R	6R	4R	9R	9R	4R	5R	4R	5R	2R			
38						1K	2K	6K													
36								4R	2R	3R	5R	5R	9R	5R	3R	2R	4R	1R	1R		
35					7K	7K	8K	2K													
33						1R	1R	5R	4R	9R	7R	7R	10R	6R	4R	3R	5R		3R		
32				3K	8K	9K	2K	4K	1K												
30							1R	4R	1R	4R	9R	3R	2R		5R	2R					
17			3K	1K	1K		5K	1K													
16						1D		2D	1D	8D	6D	1D	6D		2D	3D	3D	1D			
15							1R														
14	2K	3K	1K	2K	1K	8K	1K	2K													
13						1D	3D	3D	5D	18D	11D	9D	9D	5D	8D	3D	4D				
11	1K	4K	6K	5K	5K	4K	1K	1K													
10							3D	5D	4D	1D	5D	18D	9D	9D	6D	7D	5D	5D	2D	2D	
8	2K		3K		4K	5K															
7							3D	1D	6D	3D	5D	17D	9D	7D	10D	2D	8D	3D	1D	2D	1D
5			1K		1K																
4					1D						1D				1D						

FIGURE 8. NUMBER OF TIMES EACH COMMAND WAS CHOSEN, AS A FUNCTION OF ERROR POSITION (ORDINATE) AND SENTENCE LENGTH (ABCISSA) SUBJECT: CAROL

167

she used KILL in almost every case. For sentences longer
than 40 characters, she used DELETE/INSERT if the error
lay early in the sentence (i.e., in the group of errors
beginning at the 5th to 15th character); otherwise, she
used REPLACE.

Figure 9 shows that Sarah adopted a very similar strategy,
although the boundaries between the various regions are
not as clear. We observe more overlap between KILL and
DELETE for early errors and between KILL and REPLACE for
late errors. The use of REPLACE for an early error is
rare.

Figure 10 shows that Sue was less consistent than the other
two subjects. We observe considerable overlap between KILL
and REPLACE for late errors, and find all three commands
well represented for early errors.

Having noted the differences in the consistencies of the
subjects' strategies, let us now proceed 'o test their
optimality. Our model assumes that the subject predicts
the time it will take to correct an error using each
command, and chooses the command that maximizes $(R-C)/T$,
which is the pay rate for a command.

Figures 11, 12, and 13 show the commands chosen by each
subject as a function of KILL pay rate and DELETE/INSERT
pay rate. These figures can be divided into three regions
depending upon which command type represents the highest
pay rate. In Fig. 11, we observe that Carol could always
assure herself of a pay rate of

$$(10¢-6¢) /11 \text{ sec} = .364¢/\text{sec}$$

by choosing REPLACE. When the predicted KILL and DELETE/
INSERT pay rates (using the recalculated input models for
Carol) are both less than .364¢/sec, she should choose

Figure 9 — data grid. Rows (ordinate) = error position; columns (abscissa) = sentence length. Cell values give the count and command letter (K, D, R).

Error pos.	26/27	28/29	30/31	32/33	34/35	36/37	38/39	40/41	42/43	44/45	46/47	48/49	50/51	52/53	54/55	56/57	58/59	60/61	62/63	64/65	66/67
51													1R	2R	1R						
48											3R	5R	3R	4R		2R	1R				
47									1K	2K											
45										3R	7R	8R	3R	2R	2R		2R				
44									1K	1K	3K										
42									1R	3R	4R	4R	5R	2R	5R	2R	4R	2R			
41									8K	4K	3K	2K									
39								1R	4R	2R	5R	2R	4R	2R	3R	7R	4R				
38						2K	3K	5K	3K	1K											
36										2R	1R	3R	4R	7R	3R		3R	1R	1R		
35					7K	8K	5K	7K	5K	9K	3K	2K	1K								
33					1R	1R	1R		1R	2R	1R	8R	5R	2R	4R	3R		5R			
32				1K	4K	5K	2K	6K	5K	1K	3K	2K	1K								
30										1R		2R	6R	2R			6R	2R	1R		
17	1K			2K	3K	1K	6K	5K	1K	4K	3K										
16										1D	1D	1D	4D		2D	4D	3D	1D			
15											2R						2R				
14	2K		1K		2K	1K	6K	4K	2K	7K	4K	1K									
13								1D	3D	5D	4D	2D	6D	6D	7D	5D	5D			1D	1D
12								1R	1R				1R	1R			2R				
11	1K	2K		1K	3K	4K	6K	4K	4K	3K	8K	2K									
10				1D				2D		4D	8D	7D	7D	4D	9D	5D	2D	3D	1D	2D	
8	2K		3K		3K	6K	1K	5K	7K	1K	5K	1K									
7									1D	6D	3D	6D	8D	4D	7D	1D	2D				1D
5				1K		2K															
4												1D				2D					

FIGURE 9. NUMBER OF TIMES EACH COMMAND WAS CHOSEN, AS A FUNCTION OF ERROR POSITION (ORDINATE) AND SENTENCE LENGTH (ABCISSA) SUBJECT: SARAH

FIGURE 10. NUMBER OF TIMES EACH COMMAND WAS CHOSEN, AS A FUNCTION OF ERROR POSITION (ORDINATE) AND SENTENCE LENGTH (ABCISSA) SUBJECT: SUE

Table: Number of times each command was chosen (K, R, D), by error position (rows) and sentence length (columns).

Error pos.	40	42	44	46	48	50	52	54	56	58	60	62	64	66
51							1R	2R	1R	1R				
50						2K								
48					2R	4R	2R	2R		1R	1R			
47			2K	3K	3K	1K								
45			1R	4R	4R	1R	3R	6R		2R				
44	1K	2K	1K	1K		1K	1K							
42		3R	3R	4R	2R	3R	2R	1R	4R	1R				
41	8K	3K	3K	2K										
39	1R	4R	1R	5R	3R	4R	2R	4R	4R	5R				
38	5K	4K	2K	1K	1K		1K							
36	5R	1R	1R	4R	5R	4R	2R		5R	1R	1R	1R		
35	6K	5K	6K	1K	3K									
33	3R	2R	1R	1R	2R	-R	4R	1R	2R	2R	1R	5R		
32	4K	4K		5K		3K								
30	1R	1R		1R	6R				1R	3R				
17	3K		3K	1K		4K		1K						
16	1R		1R	R	1R		3R	3R	3R	1R				
15	2K	9K	3K	2K										
14					2D		1D		1D					
13	3R	2R	4R	4R	4R	7R	3R	6R	2R	3R				
12	2K	2K	4K	8K		3K							3D	
11	2D	3D	4D	2D	1D	3D	4D	2D		2D	2R		3D	
10	6R	4R	2R	6R	5R	1R	2R	2R						
9	2K	3K	2K	2K	K	2K	1K	5D		2D	1D			
8	2R	5R		R	2R	1R	3R							
5						1K								

Column label pairs (abscissa, sentence length):

–	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66
	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63	65	67

170

REPLACE. The "REPLACE BEST" region lies at the lower
left corner of the figure. If either the KILL or the
DELETE/INSERT pay rate is greater than .364¢/sec, she
should choose the higher of the two. The boundary between
the "KILL BEST" region and the "DELETE/INSERT BEST" region
is the diagonal line leading up and to the right, along
which the KILL and DELETE/INSERT pay rates are equal.

The first thing apparent from Figs. 11, 12, and 13 is that
the set of costs we chose for the commands failed to
ensure that each command was sometimes optimal. We observe
that Carol and Sarah should never have chosen REPLACE,
since one or both of the other commands always yielded
a higher pay rate. Sue should have used REPLACE for only
49 of her 564 commands.

The second thing apparent is that the subjects were not
nearly optimal in choosing commands. The percentages
of best, second best, and third best choices were:

	Best	Second Best	Third Best
Carol	53%	45.5%	1.5%
Sarah	47%	51.0%	1.5%
Sue	50%	31.0%	19.0%

The subjects' suboptimal choices were principally of two
types: choosing DELETE/INSERT when they should have
chosen KILL, and choosing REPLACE when they should have
chosen KILL. This observation led us to suspect that
either the subjects were consistently underestimating
KILL pay rates, or that they disliked the KILL command
enough to forego some pay to avoid using it.

We decided to proceed according to the hypothesis that
the subjects were basing their decisions on a set of

171

KILL BEST

DELETE/INSERT BEST

REPLACE BEST

FIGURE 11. NUMBER OF TIMES EACH COMMAND WAS CHOSEN, AS A FUNCTION OF KILL PAY RATE (ORDINATE) AND DELETE/INSERT PAY RATE (ABCISSA) SUBJECT: CAROL

172

KILL BEST
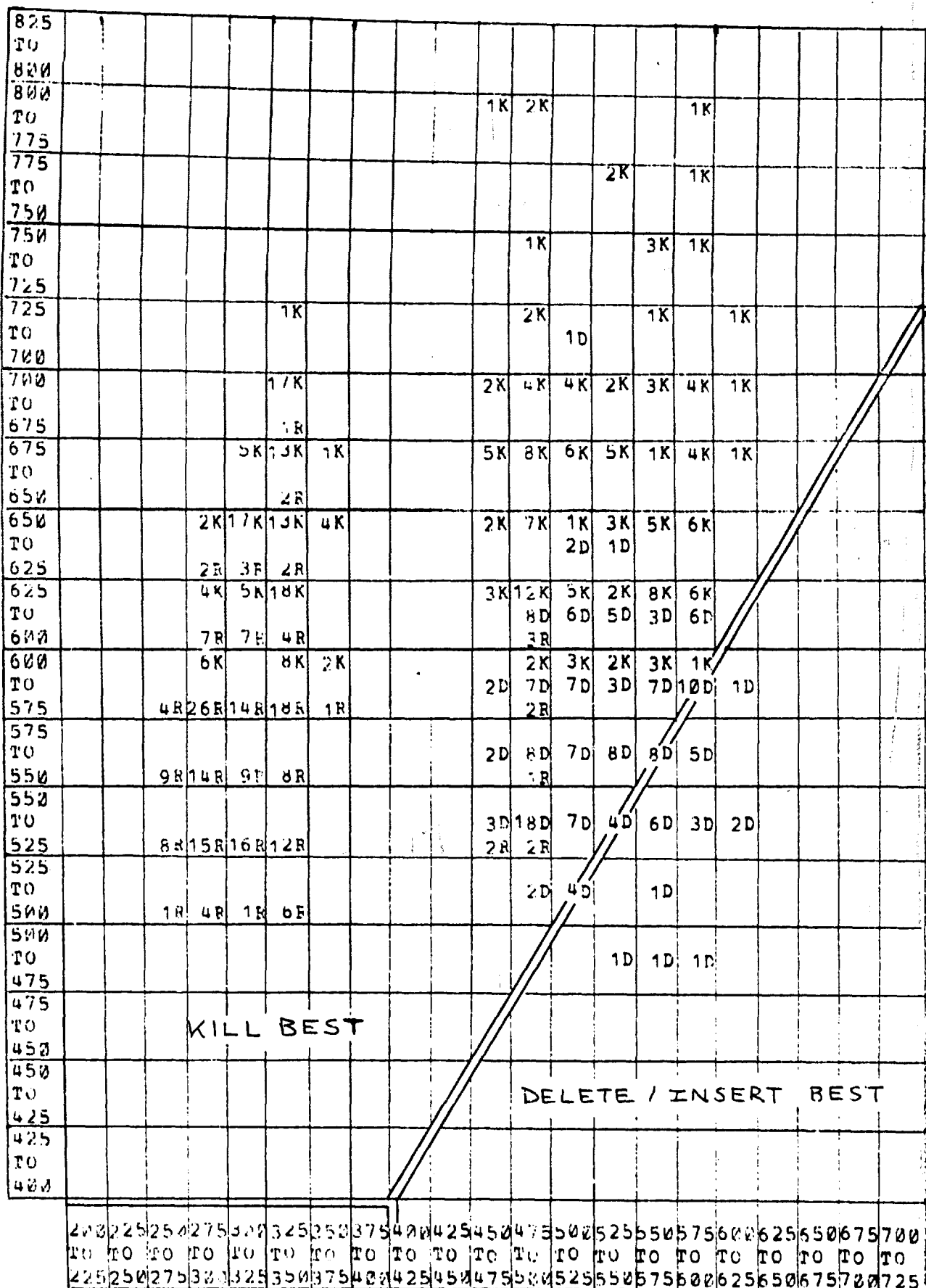
DELETE / INSERT BEST

FIGURE 12. NUMBER OF TIMES EACH COMMAND WAS CHOSEN, AS A FUNCTION OF KILL PAY RATE (ORDINATE) AND DELETE/INSERT PAY RATE (ABCISSA) SUBJECT: SARAH

173

KILL BEST

REPLACE BEST
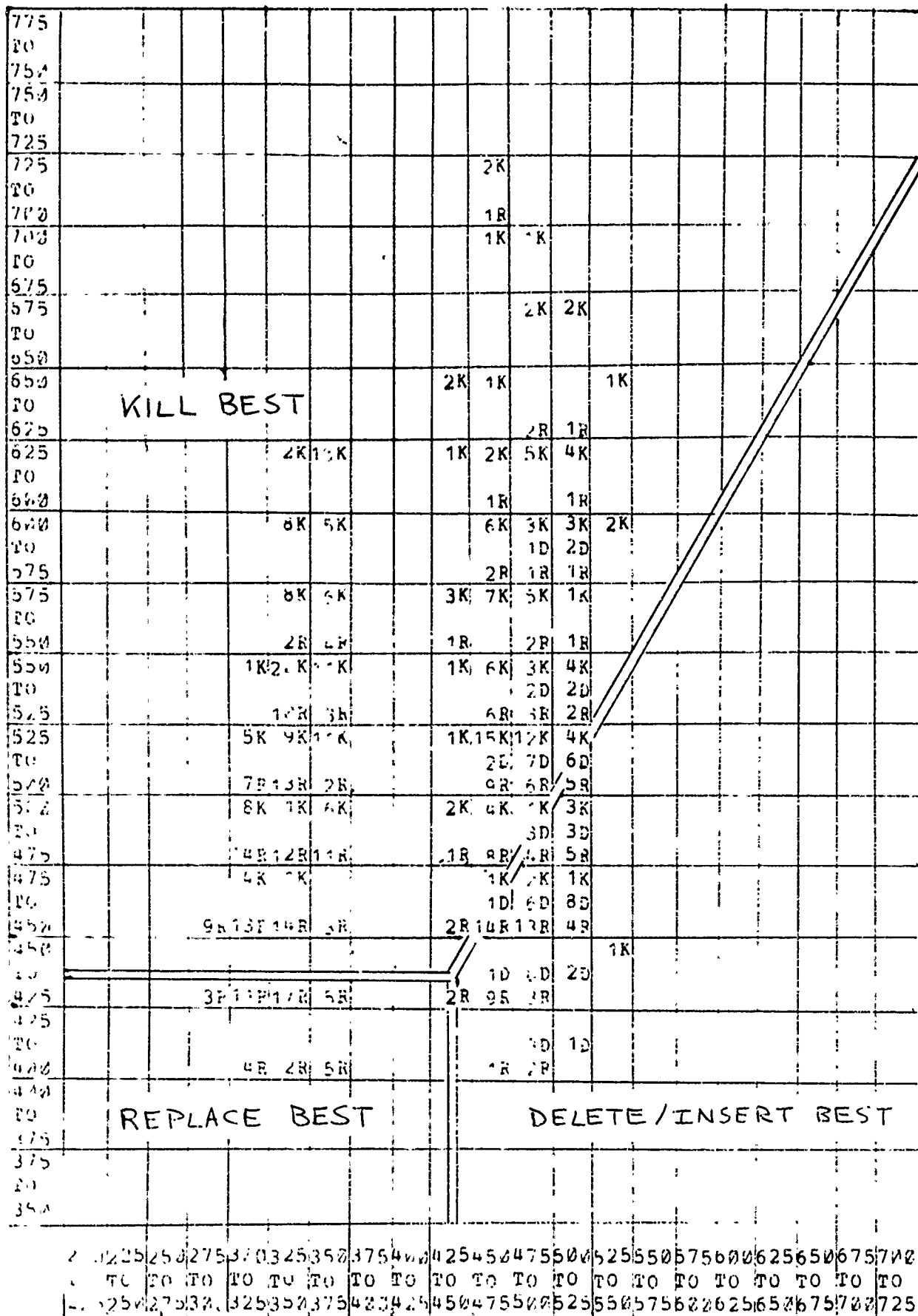
DELETE/INSERT BEST

FIGURE 13. NUMBER OF TIMES EACH COMMAND WAS CHOSEN AS A FUNCTION OF KILL PAY RATE (ORDINATE) AND DELETE/INSERT PAY RATE (ABCISSA) SUBJECT SU5

174

subjective costs, which were different from the given
costs. We set out to determine the set of costs for
which the observed strategies were most nearly optimal.

3.4.5 Calculation of Perceived Costs

The pay rate space of Figs. 11 to 13 is isomorphic to
the length vs. error position space of Figs. 8 to 10.
The transformations between the two spaces are given by
the recalculated input models. Therefore, it was a
relatively straightforward matter to deduce the set of
costs for which each subject's observed strategy is most
nearly optimal. In carrying out the calculations, the
cost of REPLACE was fixed at its given value of 6¢, and
the perceived costs of KILL and DELETE/INSERT were
calculated to the nearest half-cent.

The results were:

	KILL	DELETE/INSERT	REPLACE
		Perceived Costs	
Carol	4¢	6¢	6¢
Sarah	4¢	5.5¢	6¢
Sue	2.5¢	5.5¢	6¢
(True costs:	1¢	5¢	6¢)

The results indicate that the subjects perceived DELETE/
INSERT as costing them slightly more than they were actually
charged, and KILL as costing considerably more. Using
these subjective costs, we can plot their command choices
as functions of the subjective pay rates. This is done in
Figs. 14 to 16.

175

KILL BEST

		2K		1K
3K	3K	1K	1K
3K	1K	3K	4K	3K
1K	4K	5K	5K	4K	1K
				3D
1K 7K

1E
1 K 19K | 4K | 5K | 8K | 2K | 4K | 2K |
| | 4D | 2D | 7D | 7D | 1D |
5K 5E
1K 15K 5K | | 2K | 1K | 1K |
| 1D | 8D | 7D 10D | 6D | 2D |
17R 17P
K | 6D 33D 19D 12D 29D | 4D |
20R 46R 23E
| 4D 17D 14D 21D 12D | 4D |
27R 31R 27R 19E
| 3D 17D 14D 7D 11D | 1D |
3E2 R2 R 2E
| 2D 1D |
2R

REPLACE BEST   DELETE/INSERT BEST

250 275 300 325 350 375 400 425 450 475 500 525 550 575 600
TO TO TO TO TO TO TO TO TO TO TO TO TO TO TO
225 275 300 325 350 375 400 425 450 475 500 525 550 575 600 625

NUMBER OF TIMES EACH COMMAND WAS CHOSEN, AS A FUNCTION
OF PLAY RATE (ORDINATE) AND SUBJECTIVE DELETE/INSERT

176

KILL BEST

REPLACE BEST

DELETE / INSERT

BEST

Ordinate (top to bottom): 625 TO 600, 600 TO 575, 575 TO 550, 550 TO 525, 525 TO 500, 500 TO 475, 475 TO 450, 450 TO 425, 425 TO 400, 400 TO 375, 375 TO 350, 350 TO 325, 325 TO 300, 300 TO 275, 275 TO 250, 250 TO 225, 225 TO 200

Abscissa (left to right): 100 TO 125, 125 TO 150, 150 TO 175, 175 TO 200, 200 TO 225, 225 TO 250, 250 TO 275, 275 TO 300, 300 TO 325, 325 TO 350, 350 TO 375, 375 TO 400, 400 TO 425, 425 TO 450, 450 TO 475, 475 TO 500, 500 TO 525, 525 TO 550, 550 TO 575, 575 TO 600, 600 TO 625

Cell entries:

550 TO 525: 1K 1K

525 TO 500: 1K 2K 1K 1K

500 TO 475: 1K 1K 3K 1K ; 1D

475 TO 450: 6K 12K 2K 6K 4K 4K 6K 1K ; 1R

450 TO 425: 5K 25K 15K 7K 15K 7K 9K 6K 3K 1K ; 2D 1D ; 2R 1R

425 TO 400: 6K 18K 13K 3K 12K 5K 10K 1K 1K ; 8D 6D 6D 7D 1D ; 11R 11R 2R ; 3R

400 TO 375: 6K 1K 9K 2K 3K 4K 2K ; 3D 10D 12D 13D 16D 4D 1D ; 13R 38R 26R 13R ; 3R

375 TO 350: 4D 23D 9D 11D 9D 1D 2D ; 2R 2R ; 15R 24R 16R 9R

350 TO 325: 2D 4D 3D ; 3R 2R 3R 4R

325 TO 300: 1D

KILL BEST

REPLACE BEST

DELETE/INSERT BEST

FIGURE 16. NUMBER OF TIMES EACH COMMAND WAS CHOSEN, AS A FUNCTION OF SUBJECTIVE KILL PAY RATE (ORDINATE) AND SUBJECTIVE DELETE/INSERT PAY RATE (ABCISSA).
SUBJECT: SUE

178

Using the subjective costs, the percentage of best, second
best and third best choices became:

	BEST	SECOND BEST	THIRD BEST
CAROL	88%	12%	0%
SARAH	73%	25%	2%
SUE	68%	25%	7%

The degree to which the subjects' strategies now appear
optimal is, of course, primarily a measure of their con-
sistency.

3.4.6 Conclusions

The choice experiment has demonstrated that it is possible
to provide incentives to subjects that will affect their
choices among alternative commands in a fairly realistic
test-editing task.

On the other hand, the results indicate that even with very
explicit incentives and feedback of results, users cannot
be expected to overcome completely their preferences and
prejudices among the alternatives available to them. The
assumption that users, given adequate incentives and
information, will make optimal choices, does not appear to
be generally true. Adding incentives to a time-sharing
system will cause users to modify their behavior to some
extent in the desired way. The extent of this modification
does not appear to be predictable, because it depends on
the particular circumstances and the prejudices of the users.

4. PROGRAMMING LANGUAGES AS A TOOL FOR COGNITIVE RESEARCH

    4.1 PREFACE

    4.2 INTRODUCTORY LOGO TEACHING EXPERIMENT

         4.2.1 OBJECTIVES

         4.2.2 LESSON MATERIALS

         4.2.3 STUDENT PROJECTS

         4.2.4 CONCLUSIONS

    4.3 EXPERIMENT ON TEST VALIDITY

         4.3.1 RATIONALE AND DESIGN

         4.3.2 TEST FORMS

         4.3.3 RESULTS

    4.4 A COMPUTER-CONTROLLED VEHICLE FOR USE IN TEACHING
         PROBLEM-SOLVING

         4.4.1 ENGINEERING

         4.4.2 PROGRAM CONTROL

4.　PROGRAMMING LANGUAGES AS A TOOL FOR COGNITIVE RESEARCH

W. Feurzeig

4.1　PREFACE

Preliminary research suggested that teaching students the use of an expressive and accessible programming language such as LOGO, could provide a means of studying, diagnosing, and remedying their difficulties in solving problems. Through assessing our previous experience with the use of LOGO in mathematics teaching, and reviewing the associated problem-solving protocols generated by the students in their programming sessions, we developed a preliminary list of some conceptual barriers to the acquisition of problem-solving skills. Using this as a basis, we designed and taught a course to explore some new, and hopefully more effective, ways of introducing problem-solving concepts such as planning, modeling, and testing.

This course, described in the last technical report, was focused on *conceptual* barriers. The work described in this report has been centered on the study of some *psychological* barriers. These are not totally separable from the conceptual problems. Nevertheless, issues of motivation and relevance, and attitudes about authority and learning are the paramount or dominant problems for many pupils.

In Section 4.2, we describe a teaching experiment carried out with some pupils whose problems are essentially of this kind. Some of the lesson materials were adapted by Richard Grant from the preliminary mathematics teaching work. New course materials were designed by Wallace Feurzeig, who taught the course.

Our thinking about the problem of evaluating the teaching
experiment led us to a conjecture that standard test measure-
ments of performance underestimate the achievement levels
of low scoring subjects. To test this conjecture, we designed
and constructed an experiment on test validity. This work
is described in Section 4.3. Wallace Feurzeig designed the
test experiment. Richard Grant, Walter Weiner, and Paul
Wexelblat assisted in administering the tests. Nannette
Feurzeig and Glenn Jones analyzed the results.

The computer-controlled robot vehicle, designed to provide
a concrete framework for teaching a variety of problem-
solving tasks, was described in the last report. A hardware
prototype is being constructed by Paul Wexelblat and Frank
Frazier. It is described in Section 4.4.

4.2 INTRODUCTORY LOGO TEACHING EXPERIMENT

In this section we describe an experimental course conducted
with a small class of eighth-grade students at the Muzzey
Junior High School in Lexington, Massachusetts from March,
1970 through June, 1970. A reasonable name for the course
might have been: an introduction to LOGO as a tool for
motivating formal, constructive modes of thinking.

4.2.1 Objectives

The main thrust of the teaching was to explore the use of
LOGO as a way of "turning-on" pupils who were alienated
from intellectual activity, and who eschewed serious par-
ticipation in (the non-social aspects of) regular classroom
work. We selected for our class six eighth-graders who had
a previous history of difficulties with formal, symbolic
subjects -- not only with mathematics and science, but even
with basic skills such as reading. In fact, we chose the
six pupils with the greatest deficiencies in reading com-
prehension varying from three to five years below standard
(eighth) grade level -- and with no indication of organic
difficulties such as hearing problems or brain damage.

The IQ levels of the students averaged about 100 with extremes
of 87 and 117. All in the group were underachievers in
the sense that they had the potential for performing a great
deal better. We felt that two of the students in particular
were performing enormously lower than their capabilities.

Our main goal was to see whether we could better understand
the psychological or other barriers to learning of these
students through getting them involved with LOGO.

We believed that they would find the use of LOGO on the
computer so compelling as to willingly engage in reading and
problem-solving work. To facilitate their introduction to
LOGO, we wished to give them very simple material with
which they could experience evident success. Thus, we started
them off with some LOGO programmed lessons which had pre-
viously been used successfully by second and third graders
as well as secretaries and clerks. These easy lessons
also had the side advantage that they heavily involved the
students in the activity of reading, which they much needed.

4.2.2 Lesson Materials

The teaching involved three kinds of activities. (1) Students
worked through a series of 24 programmed lessons on LOGO
programming at the terminal, individually or occasionally in
pairs. (2) There was an occasional blackboard presentation
of new material along with a discussion of current problems.
(3) Students worked on various projects, usually of their
own choice and on their own initiative, even when requiring
a great deal of guidance.

The programmed lessons were written in LOGO itself in an
interactive mode and in a relatively open-ended style, mixing
straight exposition and test items, with freer problem
assignments calling for the student to write his own procedures.

In the following pages, extracts from student interaction with
three lessons are reproduced to illustrate the type of material
presented in the lessons and its mode of use by the students.
The student's inputs are underscored to distinguish these from
the computer's typing.

◦GET LESSON TEN
(HOARDED)(TO BEGIN TYPE "TEACH-THE-COMPUTER" 3:10 PM 10/24/1969)
◦TEACH-THE \-COMPUTER

THE COMPUTER ALREADY KNOWS ABOUT SOME PROCEDURES LIKE WORD, SENTENCE,
FIRST, BUTLAST AND SOME OTHERS WE HAVE LEARNED. @

NOW LET'S TEACH IT SOMETHING NEW, THAT IT DOESN'T KNOW ALREADY. @

FIRST WE HAVE TO TELL IT THAT WE ARE GOING TO TEACH IT SOMETHING NEW. I
WILL SHOW YOU HOW TO DO THIS. @

FIRST I WILL TYPE THE WORD - TO.

TO

THEN I WILL GIVE THE NEW PROCEDURE A NAME. THE NAME OF MY NEW PROCEDURE
IS SPELLCAT. @

TO SPELLCAT

NOW I AM GOING TO TELL IT WHAT SPELLCAT IS SUPPOSED TO DO. I WANT
SPELLCAT TO DO THREE THINGS IN ORDER.@

I WILL NUMBER EACH STEP SO THE COMPUTER WILL KNOW THE RIGHT ORDER TO DO
THESE THINGS. @

```
TO SPELLCAT
10 PRINT "C"
20 PRINT "A"
30 PRINT "T"
```

NOW I HAVE TOLD THE COMPUTER THE THREE THINGS WHICH SPELLCAT SHOULD DO.
@

NOW I WILL TYPE END, TO LET THE COMPUTER KNOW I HAVE FINISHED TELLING
IT HOW TO SPELLCAT. @

```
TO SPELLCAT
10 PRINT "C"
20 PRINT "A"
30 PRINT "T"
END
```

THE COMPUTER WILL NOW TYPE BACK -- SPELLCAT DEFINED. IT IS TELLING ME
THAT IT NOW UNDERSTANDS SPELLCAT. @

HERE IS THE WAY IT WILL LOOK.

```
TO SPELLCAT
10 PRINT "C"
20 PRINT "A"
30 PRINT "T"
END
SPELLCAT DEFINED      .
```

NOW LET'S TRY THIS PROCEDURE TO SEE WHAT IT WILL DO. YOU TYPE -
SPELLCAT.

```
*SPELLCAT
C
A
T
```

NOW TRY WRITING YOUR OWN THING. HERE IS A SUGGESTION IF YOU NEED ONE. @

YOU MIGHT WRITE A PROCEDURE WHICH COUNTS LIKE THIS:

```
ONE
TWO
THREE
FOUR
FIVE
```

GOOD LUCK.

```
-TO SPELL12345
>10 PRINT "ONE"
>20 PRINT "TWO"
>30 PRINT "THREE"
>40 PRINT "FOUR"
>50 PRINT "FIVE"
>END
SPELL12345 DEFINED

-SPELL12345
ONE
TWO
THREE
FOUR
FIVE
```

186

```
→GET LESSON TWENTY-ONE
(HOARDED)(TO BEGIN TYPE "USEMYSTERIES". 4:28 PM 11/13/1969)
→
 USEMYSTERIES
I AM GOING TO SHOW YOU SOME PROCEDURES AND ASK YOU TO PRETEND TO BE THE
COMPUTER. ⌄

HERE IS THE FIRST PROCEDURE.

TO MYSTERY-1 /ANYWORD/
10 PRINT WORD OF BUTFIRST OF /ANYWORD/ AND FIRST OF /ANYWORD/
END


IF YOU WERE THE COMPUTER, WHAT WOULD YOU ANSWER IF YOU WERE GIVEN THIS
INSTRUCTION:
MYSTERY-1 "SOAK"
*SOAKS
PLEASE TRY AGAIN.
*OAKS

GREAT! HERE IS THE NEXT QUESTION. WHAT WOULD YOU ANSWER TO THIS
INSTRUCTION:
MYSTERY-1 "312"
*123

RIGHT! HERE IS THE LAST QUESTION ABOUT THIS PROCEDURE. WHAT WOULD YOU
ANSWER?
MYSTERY-1 "EAR"
*ARE

GOOD FOR YOU. NOW LET'S LOOK AT ANOTHER PROCEDURE.

TO MYSTERY-2 /FIRST WORD/ AND /SECOND WORD/
10 PRINT WORD OF /SECOND WORD/ AND /FIRST WORD/
END


THE FIRST QUESTION:
MYSTERY-2 "AT" AND "BE"
*BE AT
PLEASE TRY AGAIN.
*BEAT

RIGHT! NEXT QUESTION:
MYSTERY-2 "12" AND "24"
*2412

GOOD! NOW HERE IS THE THIRD PROCEDURE:

TO MYSTERY-3 /FIRST NUMBER/ AND /SECOND NUMBER/ AND /SIGN/
10 PRINT WORD OF /FIRST NUMBER/ AND WORD OF /SIGN/ AND /SECOND NUMBER/
END
```

187

```
FIRST QUESTION:
MYSTERY-3 "5" AND "9" AND "+"
*5+9

GREAT! SECOND QUESTION:
MYSTERY-3 "1" AND "2" AND "/"
*1/2

I HAVE THREE MYSTERY PROCEDURES -- MYSTERY-4, MYSTERY-5, AND MYSTERY-6.

FIRST YOU ARE TO LIST MYSTERY-4.

THEN YOU ARE TO TRY MYSTERY-4 WITH YOUR OWN INPUTS.

WHEN YOU ARE SURE THAT YOU CAN GET MYSTERY-4 TO WORK WITHOUT ANY
COMPLAINTS FROM THE COMPUTER, DO THE SAME THING WITH MYSTERY-5.

FINALLY, WHEN MYSTERY-5 WORKS, DO THE SAME THING WITH MYSTERY-6.

GOOD LUCK! WHEN YOU HAVE FINISHED, TYPE -- SURPRISE -- FOR SOME FUN.

 LIST MYSTERY-4

TO MYSTERY-4 /FIRST NAME/ AND /MIDDLE NAME/ AND /LAST NAME/
10 PRINT WORD OF FIRST OF /FIRST NAME/ AND WORD OF FIRST OF /MIDDLE
   NAME/ AND FIRST OF /LAST NAME/
END

→MYSTERY-4 "AXEL" "BOX" "CAKE"
ABC

 LIST MYSTERY-5

TO MYSTERY-5 /NUMBER/
10 PRINT DIFFERENCE OF /NUMBER/ AND /NUMBER/
END

→MYSTERY-5 123456789
0

 LIST MYSTERY-6

TO MYSTERY-6 /BIRTH MONTH/ AND /DAY/ AND /AGE/
10 PRINT SENTENCE OF "MY BIRTHDAY IS" AND SENTENCE OF /BIRTH MONTH/
   AND /DAY/
20 PRINT SENTENCE OF "I AM" AND SENTENCE OF /AGE/ AND "YEARS OLD."
END

→MYSTERY-6 "MARTOBER" 67 "ONE THOUSAND"
MY BIRTHDAY IS MARTOBER 67
I AM ONE THOUSAND YEARS OLD.
```

188

→GET LESSON TWENTY-FOUR
(HOARDED)(TO BEGIN TYPE "START". 11:58 AM 11/17/1969)
→START

HERE IS A PROCEDURE WE USED WHEN WE FIRST STARTED WORKING WITH THE
COMPUTER. ⌄

FIRST ASK THE COMPUTER TO -- LIST SAYHI. ⌄

THEN TRY OUT SAYHI TO SEE WHAT IT DOES. ⌄

WHEN YOU ARE READY TO GO ON, TYPE -- MORE.
→
→LIST SAYHI

TO SAYHI
10 PRINT "HI"
20 SAYHI
END

→SAYHI
HI
HI
HI
HI
HI
HI
HI
HI
HI
HI
HI
HI
HI
HI
HI
HI
HI
HI   (At this point the student stopped the program by
                hitting the break key.)

I WAS AT LINE 10 IN SAYHI.

→MORE

NOW IT'S YOUR TURN TO WRITE A PROCEDURE. ⌄

TRY TO WRITE A PROCEDURE WHICH WILL PRINT OUT YOUR NAME JUST THE WAY
SAYHI PRINTED HI. ⌄

WHEN IT WORKS, TYPE -- NEXT -- FOR ANOTHER SUGGESTION.
→
```
 TO SAYSAM
>10 PRINT "SAM"
>20 SAYSAM
>END
SAYSAM DEFINED
```
→

```
 SAYSAM
SAM
SAM
SAM
SAM
SAM
SAM
SAM
```
(The student stopped his program here).

I WAS AT LINE 10 IN SAYSAM.

→NEXT

NOW ARE YOU READY FOR THE CHALLENGE? ANSWER YES OR NO.
*YES
THIS TIME TRY TO WRITE A PROCEDURE THAT WILL WORK ON ANY WORD YOU GIVE
IT. ✓

PLEASE CALL YOUR PROCEDURE -- WORK. IF I USED YOUR PROCEDURE AND SAID
WORK "MARGE" IT WOULD TYPE -- MARGE -- RIGHT DOWN THE PAGE. ✓

HOW ABOUT IT? ARE YOU GAME? GOOD LUCK!
→
```
 10 WORK /ANYTHING/
>10 PRINT /ANYTHING/
>20 WORK /ANYTHING/
>END
WORK DEFINED
```
→

```
 WORK "THIS IS THE END. GOODBYE..."
THIS IS THE END. GOODBYE...
THIS IS THE END. GOODBYE...
THIS IS THE END. GOODBYE...
THIS IS THE END. GOODBYE...
THIS IS THE END. GOODBYE...
THIS IS THE END. GOODBYE...
```
```
          |        |        |
          |        |        |
 ✓        |        |        |
```

4.2.3 Student Projects

LOGO turned out to be useful to some students in real
situations that developed in their daily lives. It was on
these occasions that some of the most important problem-
solving concepts were concretized and comprehended. For
one student, the elementary notion of a LOGO procedure
was first consolidated through a project that arose from
an altercation he had with a school bus driver:

(1) Affidavit

He described his fight and his **grievances** with the driver,
and asked for help to decide what he should do about it. He
was advised to put his complaint in writing, stating all
relevant facts, witnesses, etc. He might then present it to
to the principal, to the bus company, and conceivably to
his mother's attorney!

In order to make these, and possibly other copies that
might be needed, he wrote his complaint as a LOGO program,
TO COMPLAIN, and saved it in computer memory. The first
part of the resulting program is listed next.

```
10 COMPLAIN
10 PRINT "ON THE DAY OF MAY 4, 1970 THE BUS DRIVER TOLD ME TO GET OFF
   THE BUS AND I SAID ,WHY AND HE SAID GET OFF THE BUS AND I DIDN'T ."
20 PRINT "HE WANTED ME OFF BECAUSE OF MY BUS PASS AND I SAID IT WAS ALL
   RIGHT HE HAD SAID, REFURE TO GET IT CHANGED AND I DID BY MR. TERRY
   AND HE PUT A 14 IN THE MIDDLE OF THE CARDA AND HE WANTED A NOTE FROM
   MR. TERRY AND HE WANTED IT ON MAY 4, 1970."
30 PRINT "THE DAY THAT IT HAPPEN WAS ON MAY 1, 1970 AND I TOLD HIM I WAS
   GOING TO WALK TO SCHOOL THAT DAY."
40 PRINT "AND ON MAY 4, 1970 I GOT ON THE BUS AND I SHOWED HIM MY PASS
   AND HE SAID GET OFF AND SAID NO ,HE GOT OUT OF HIS SEAT AND GRABED
   ME AND TOLD HIM TO LET GO AND DIDN'T ."
50 PRINT "HE TRYED TO TRIP ME AND THEN HE STARTED TO PUSH ME AROUND AND
   AS HE WAS PUSH ME OFF THE BUS HE WAS KNOCKING DOWN OTHER PEOPLE."
60 PRINT "HE TOLD MR. TERRY WHAT HAPPEN AND HE SAID HE HAD ROAD BUS 15
   AND I TOLD MR. TERRY THAT I ROAD BUS 14 AND I COULD PROVE THAT I WAS
   ON BUS 14 ."
```

Whenever he wished to get copies of the program he merely
retrieved his file and invoked the program as follows.

```
→COMPLAIN
ON THE DAY OF MAY 4, 1970 THE BUS DRIVER TOLD ME TO GET OFF THE BUS AND
I SAID ,WHY AND HE SAID GET OFF THE BUS AND I DIDN'T .
HE WANTED ME OFF BECAUSE OF MY BUS PASS AND I SAID IT WAS ALL RIGHT HE
HAD SAID, BEFORE TO GET IT CHANGED AND I DID BY MR. TERRY AND HE PUT A
14 IN THE MIDDLE OF THE CARDA AND HE WANTED A NOTE FROM MR.TERRY AND
HE WANTED IT ON MAY 4, 1970.
THE DAY THAT IT HAPPEN WAS ON MAY 1,1970 AND I TOLD HIM I WAS GOING TO
WALK TO SCHOOL THAT DAY.
AND ON MAY4,1970 I GOT ON THE BUS AND I SHOWED HIM MY PASS AND HE SAID
GET OFF AND SAID NO ,HE GOT OUT OF HIS SEAT AND GRABED ME AND TOLD HIM
TO LET GO AND DIDN'T .
HE TRYED TO TRIP ME AND THEN HE STARTED TO PUSH ME AROUND AND AS HE WAS
PUSH ME OFF THE BUS HE WAS KNOCKING DOWN OTHER PEOPLE.
HE TOLD MR.TERRY WHAT HAPPEN AND HE SAID HE HAD ROAD BUS 15 AND I TOLD
MR. TERRY THAT I ROAD BUS 14 AND I COULD PROVE THAT I WAS ON BUS 14 .
```

        .   .   .
        .   .   .
        .   .   .

The procedure TO COMPLAIN is an instance of an elementary
form -- it merely directs the printing of a series of literal
sentences. Nonetheless, and even though he never pressed the
complaint, it served the student well. It was the first time he
truly comprehended the meaning of a procedure, how to organize
and express a sequence of instructions, and the distinction
between defining a procedure and executing it.

(2) Rights of Passage

During the first week of the course, one of the students,
with wicked gleams in both eyes, asked if we could write a
program together to generate a student pass. A student pass
is ordinarily written by a teacher to give a student legal
passage from one point to another through the school, during
class periods, when students are normally restricted to their
currently scheduled classrooms.

This enterprising student had the (false) notion that, with
a means of generating a pass from the computer room at any
time and to any place in the school, he would have free,
legal passage to wander through the school at will all day
long. Also, he simply reveled in working out any scheme for
"beating the system" in general and particularly when
plotting anti-school-establishment projects and capers, big
and small.

He was utterly surprised when the answer to his suggestion
was affirmative. The resulting program, TO PASS, as with
TO COMPLAIN, is an elementary form, a series of literal PRINT
commands. The procedure is listed next.

```
 TO PASS
>5 PRINT "BILLY HOSFORD"
>10 PRINT "TO CLASS"
>15 PRINT "FROM COMPUTER"
>20 PRINT TIME
>25 PRINT DATE
>30 PRINT "MR. FEURZEIG"
>END
PASS DEFINED
```

When the procedure is executed, it produces the following
counterfeit pass.

```
 PASS

BILLY HOSFORD
TO CLASS
FROM COMPUTER
10:37 PM
7/15/1970
MR. FEURZEIG
```

The procedure TO PASS was the first of a series of four
programs which successively extended the intended scope of
passes which could be generated. The first idea was to

193

extend the procedure to permit *any* teacher's name to be
affixed to the pass, by making the teacher's name an input.

```
TO PASS-1 /TEACHER/
5 PRINT "BILLY HOSFORD"
10 PRINT "TO CLASS"
15 PRINT "FROM COMPUTER"
20 PRINT TIME
25 PRINT DATE
30 PRINT /TEACHER/
END
```

This procedure was invoked as follows.

```
PASS-1 "MRS. SMITH"
```

```
BILLY HOSFORD
TO CLASS
FROM COMPUTER
9:13 AM
3/26/1970
MRS. SMITH
```

In its final form, the pass generating procedure had three
inputs: the name of the student, his specific class and
room destination, and the name of the teacher approving the
pass.

```
TO CLASSPASS /PERSON/ /CLASS/ /TEACHER/
5 PRINT /PERSON/
10 PRINT /CLASS/
15 PRINT "FROM COMPUTER"
20 PRINT TIME
25 PRINT DATE
30 PRINT /TEACHER/
END
```

Thus, an unlikely invocation of this procedure could be:

CLASSPASS "DENNIS THE MENACE" "SCIENCE 201" "MR. GATTO"

```
DENNIS THE MENACE
SCIENCE 201
FROM COMPUTER
10:42 PM
7/15/1970
MR. GATTO
```

The student who thought up this project never actually used
a pass generated from these programs. Neither did other
students, so there were no instances of illegal passage.

But the sense that they *could have* done so was important to
them. At the same time, the conceptual benefit from this
project was in illuminating the notion and use of procedures
with inputs, and illustrating the utility of the concept
of naming in extending the scope of application of pro-
cedures.

(3) Drawing Pictures

Several students liked to doodle, draw pictures and designs,
do lettering, and the like. They knew that LOGO could be
used to write procedures for printing pictures. Thus,
they all were familiar with the LOGO program called SNOOPY
whose effect when executed is as follows.

```
    XX        XXXXXXX    XXXXXXX    XXXXXXX
    XX        XXXXXXX    XXXXXXX    XXXXXXX
    XX        XX   XX    XX   XX    XX   XX
    XX        XX   XX    XX         XX   XX
    XX        XX   XX    XX         XX   XX
    XX        XX   XX    XX XXXX    XX   XX
    XX        XX   XX    XX XXXX    XX   XX
    XX        XX   XX    XX   XX    XX   XX
    XXXXX     XXXXXXX    XXXXXXX    XXXXXXX
    XXXXX     XXXXXXX    XXXXXXX    XXXXXXX
```


196

```
MM                        MM
M M                    M M     MMMMMMMMMM      K          K    MMMMMMMMMM
M   M                 M  M         M         K       K        M
M     M              M   M         M         K     K          M
M       M           M    M         M         K   K            M
M        M        M      M         M         K K              M
M          M     M       M         M         KK              .
M            M M         M         M         KKK              MMMMMMMM
M             MM         M         M         K  K             M
M                        M         M         K   K            M
M                        M         M         K     K          M
M                        M         M         K       K        M
M                        M    MMMMMMMMMM     K          K     M MMMMMMMMMMMM
```

Finally, one of the students asked how he could write pr. ram.
to make pictures. The initial suggestion was based on the
observation that each line of the SNOOPY drawing is compose:
of a succession of marks (whether 0's or X's or 1's or over-
prints of these) °ollowed by blank spaces.

Further, he was told about the Logo TYPE command which is
like PRINT except that it does not carriage return after
printing. (Thus TYPE is used when one wants to get several
different words or sentences printed in the same line).
The effect of TYPE "X" is simply to print-out X; the effect
of TYPE /BLANK/ is to print-out a blank space; the effect of
PRINT"" or of PRINT /EMPTY/ is simply to perform a carriage
return, i.e. to start the next line.

With this information, the student wrote the following
program:

```
 TO MAKE-A-BOX
>10 TYPE "X"
>20 TYPE "X"
>30 TYO-PE "X"
>40 TYPE "X"
>50 TYPE "X"
>60 TYPE "X"
>70 PRINT ""
>80 TYPE "X"
>90 TYPE /BLANK/
>100 TYPE /BLANK/
>110 TYPE /BLANK/
>120 TYPE /BLANK/
>130 TYPE "X"
>140 PRINT ""
>150 TYPE "X"
>160 TYPE /BLANK/
>170 TYPE /BLANK/
>180 TYPE /BLANK/
>190 TYPE /BLANK/
>200 TYPE "X"
>210 PRINT ""
>220 TYPE "X"
>230 TYPE /BLANK/
>240 TYPE /BLANK/
>250 TYPE /BLANK/
>260 TYPE /BLANK/
>270 TYPE "X2-"
>280 PRINT ""
>290 TYPE "X2-"
>300 TYPE"-"- "X"
>310 TYPE "X"
>320 TYPE "X"
>330 TYPE "X"
>340 TYPE "X"
>350 PRINT ""
>END
MAKE-A-BOX DEFINED
-
```

the effect of the program is:

MAKE-A-BOX

```
XXXXXX
X    X
X    X
X    X
XXXXXX
-
```

198

The student was not at all put off by the tedious monotony
of writing the long list of TYPE commands which, point by
point and space by space, defined the drawing. Nor was he
bothered by the fact that each new drawing would require a
comparably detailed lattice of petty-point work from him.
He was quite willing at this point to start on the considerably
more detailed picture he had in mind as his real goal.

Nevertheless, when the point was made that a single procedure
could be written to type a whole series of adjacent marks
(or spaces) of any length, he was very interested. After
considerable consultation, guidance, and hand-holding two
procedures, DRAW and NEXT, were written. DRAW /LETTER/ /N/
types /LETTER/, whatever character or word or sentence it is,
/N/ successive times in a row. NEXT simply returns the
carriage for the next line.

```
←TO DRAW /LETTER/ /N/
>10 TEST IS /N/ 0
>20 IF TRUE STOP
>30 TYPE /LETTER/
>40 DRAW /LETTER/ DIFF OF /N/ AND 1
>END
DRAW DEFINED
←
```

```
←TO NEXT
>10 PRINT /EMPTY/
>END
NEXT DEFINED
←
```

DRAW is basically an iterative procedure. It types /LETTER/
and then does the same thing /N/-1 times more (in LOGO
notation, DIFF OF /N/ AND 1 times more) until the number of
times left to do it becomes zero. DRAW and NEXT are used to
draw a box like that of MAKE-A-BOX, thusly:

199

```
←TO BOX
>10 DRAW "X" 6
>20 NEXT
>30 DRAW "X" 1
>40 DRAW /BLANK/ 4
>50 DRAW "X" 1
>60 NEXT
>70 DRAW "X" 1
>80 DRAW /BLANK/ 4
>90 DRAW "X" 1
>100 NEXT
>110 DRAW "X" 1
>120 DRAW /BLANK/ 4
>130 DRAW "X" 1
>140 NEXT
>150 DRAW "X" 6
>160 NEXT
>END
BOX DEFINED
←
```

The effect of this procedure is:

```
 ←BOX


 XXXXXX
 X    X
 X    X
 X    X
 XXXXXX
 ←
```

DRAW and NEXT were used in procedures for generating other
simple figures, such as the following indented triangle,
with comparable ease.

←TRIANGLE

```
         X
        X X
       X   X
      X     X
     X       X
    XXXXXXXXXXX
```

One further level of sophistication was suggested -- writing
a procedure to type out a whole line of a drawing at a time.
The idea was straightforward. The input to the procedure
would be a list of pairs of words -- the first word in each
pair would be the character to be typed (X or a blank or
anything else that is printable) and the second word would
be the number of times that character was to be typed. Thus,
the list " X 15 Y 2 " would be interpreted as type X 15 times
and then type Y 2 times.

The resulting procedure, DRAWLINE, was too difficult for
the student to write himself, but he did understand its
operation.

```
TO DRAWLINE /LIST/
10 TEST IS /LIST/ /EMPTY/
20 IF TRUE PRINT /EMPTY/
30 IF TRUE STOP
40 DRAW (FIRST OF /LIST/) (FIRST OF BUTFIRST OF /LIST/)
50 DRAWLINE (BUTFIRST OF BUTFIRST OF /LIST/)
END
```

DRAWLINE works on /LIST/ as follows. When /LIST/ becomes
empty, DRAWLINE returns the carriage for the next line and
then stops. Prior to that point, DRAWLINE peels off the first
two words from /LIST/, and hands them over as inputs to DRAW,
the previously written procedure discussed above. DRAW
carries out the   typing specified by that pair of words.
DRAWLINE then repeats the whole process again, with the
remaining part of /LIST/ (i.e. BUTFIRST OF BUTFIRST OF /LIST/.)

The use of DRAWLINE is illustrated next in drawing an indented
diamond. Line 1Ø of the procedure DIAMOND causes DRAWLINE
to make 2Ø blank spaces and then 1 X; line 2Ø calls for 19
blank spaces, 1 X, 1 blank space, and then 1 X; and so on.
(The invisible blank space is typed in on the teletype using

201

the special CONTROL key with a B for blank).

```
TO DIAMOND
10 DRAWLINE "  20 X 1"
20 DRAWLINE "  19 X 1    1 X 1"
30 DRAWLINE "  18 X 1    3 X 1"
40 DRAWLINE "  17 X 1    5 X 1"
50 DRAWLINE "  16 X 1    7 X 1"
60 DRAWLINE "  15 X 1    9 X 1"
70 DRAWLINE "  16 X 1    7 X 1"
80 DRAWLINE "  17 X 1    5 X 1"
90 DRAWLINE "  18 X 1    3 X 1"
100 DRAWLINE "  19 X 1    1 X 1"
110 DRAWLINE "  20 X 1"
END
```

Using DIAMOND results in:

DIAMOND

```
           X
          X X
         X   X
        X     X
       X       X
      X         X
       X       X
        X     X
         X   X
          X X
           X
```

An important pay-off from the use of these drawing procedures
from the student's vantage point, was their specific application
to a project that he cherished. The result was a drawing
made by his procedure RAQUEL. (The drawing though relatively
artful and harmless enough, is not reproduced here.)

From our vantage point, the series of drawing projects was
exceptionally valuable as a context for illustrating how
more general, powerful, and expressive problem-solving pro-
cedures often are evolved in intellectual work.

(4) <u>Roulette</u>

The students played a number of games at the computer, including
TIC-TAC-TOE, NIM, HANGMAN, WORDHUNT, and THIRTY-ONE.   They
liked to work with interactive programs generally, including
simple arithmetic quizzes ("tests") as well as games ("fun").
Some of the students wrote their own quizzes and games.   One
such project was a ROULETTE game, the first version of which
is illustrated in the following interactive transcript.

```
 ROULETTE
YOU HAVE $100 BILL THE HOUSE LIMIT IS $100 . YOU MUST BET 1.00 OR MORE
NO LESS.
100
THE WHEEL SPINS PLACE YOUR BET ON . 1) A SINGLE NUMBER. 2) ANY TWO
NUMBER 3) ANY THREE NUMBERS.
*2
HOW MUCH DO YOU BET ?
*63
WHAT NUMBER ARE YOU BETING ON
*4
13
YOUR TOTAL IS
37
DO YOU WANT TO PLAY AGAIN IF SO PRINT YES
*YES
37
THE WHEEL SPINS PLACE YOUR BET ON . 1) A SINGLE NUMBER. 2) ANY TWO
NUMBER. 3) ANY THREE NUMBERS.
*3
HOW MUCH DO YOU BET ?
*15
WHAT NUMBER ARE YOU BETING ON
*23
433
YOUR TOTAL IS
22
DO YOU WANT TO PLAY AGAIN IF SO PRINT YES
*YES
22
THE WHEEL SPINS PLACE YOUR BET ON . 1) A SINGLE NUMBER. 2) ANY TWO
NUMBER. 3) ANY THREE NUMBERS.
*1
HOW MUCH DO YOU BET ?
*22
WHAT NUMBER ARE YOU BETING ON
*20
9
YOU HAVE LOST TO THE HOUSE
```

.   .   .
.   .   .
.   .   .

203

The associated procedure is:

```
TO ROULETTE (PART ONE)
10 PRINT "YOU HAVE $100 BILL THE HOUSE LIMIT IS $100 . YOU MUST BET
   1.00 OR MORE NO LESS."
11 MAKE
   NAME:  "POT"
   THING:  "100"
15 PRINT /POT/
20 PRINT "THE WHEEL SPINS PLACE YOUR BET ON . 1) A SINGLE NUMBER. 2)
   ANY TWO NUMBER. 3) ANY THREE NUMBERS."
40 MAKE
   NAME:  "X"
   THING:  REQUEST
50 TEST IS /X/ "1"
52 IF TRUE MAKE
   NAME:  "NUM"
   THING:  RANDOM
54 IF TRUE GO TO LINE "80"
56 IF FALSE GO TO LINE "60"
60 TEST IS /X/ "2"
62 IF TRUE MAKE
   NAME:  "NUM"
   THING:  WORD OF RANDOM RANDOM
64 IF TRUE GO TO LINE "80"
66 IF FALSE GO TO LINE "70"
70 TEST IS /X/ "3"
72 IF TRUE MAKE
   NAME:  "NUM"
   THING:  WORD OF WORD OF RANDOM RANDOM RANDOM
74 IF TRUE GO TO LINE "80"
76 IF FALSE GO TO LINE "80"
80 PRINT "HOW MUCH DO YOU BET ?"
82 MAKE
   NAME:  "N"
   THING:  REQUEST
83 TEST IS /POT/ MAXIMUM /N/ /POT/
84 IF FALSE PRINT "YOU DO NOT HAVE THAT MUCH CASH TRY AGAIN"
85 IF FALSE GO TO LINE "80"
86 PRINT "WHAT NUMBER ARE YOU BETING ON"
87 MAKE
   NAME:  "X"
   THING:  REQUEST
89 PRINT /NUM/
90 TEST IS /X/ /NUM/
93 IF TRUE MAKE
   NAME:  "POT"
   THING:  SUM OF /POT/ AND /N/
95 IF FALSE MAKE
   NAME:  "POT"
   THING:  DIFFERENCE OF /POT/ AND /N/
100 TEST IS /POT/ "0"
103 IF TRUE PRINT "YOU HAVE LOST TO THE HOUSE"
104 IF FALSE PRINT "YOUR TOTAL IS"
105 PRINT /POT/
```

```
107 PRINT "DO YOU WANT TO PLAY AGAN IF SO PRINT YES"
110 MAKE
      NAME:   "ANS"
      THING:  REQUEST
111 TEST IS /ANS/ "YES"
113 IF TRUE GO TO LINE "15"
114 IF FALSE END
END
```

The procedure is impressive for its existence rather than
for its elegance (or even correctness). The task was a
formidable one for the student. He undertook it on his own
initiative, and did most of the debugging himself. Sub-
sequently, he extended the procedure considerably. The use
of a later version of ROULETTE is illustrated in the following
interactions.

```
ROULETTE

YOU START WITH A $100 BILL. $100 IS THE HOUSE LIMIT. YOU MUST BET $1 OR
MORE.
THE WHEEL SPINS. PLACE YOUR BET ON (1) A SINGLE NUMBER. (2) ANY TWO
NUMBERS. (3)ANY THREE NUMBERS (4) ANY FOUR NUMBERS .(5) ANY SIX
CONSECUTIVE NUMBERS. ((6) TWELVE CONSECUTIVE NOS. (7) ANY 18
CONSECUTIVE NOS. (8) ALL ODD OR EVEN NOS.
*1
HOW MUCH MONEY DO YOU BET?
*50
OK, YOU HAVE DECIDED TO BET ON ONE SINGLE NUMBER. YOU MAY BET ON ANY
NUMBER, 0-36. IF YOU BET ON ONE NUMBER 1-36 AND THE NUMBER IS 0 YOU MAY
KEEP YOUR BET ON THE TABLE FOR THE NEXT BET. WHAT NUMBER DO YOU BET
YOUR MONEY ON?
*33
I'M AFRAID YOU HAVE LOST YOUR BET.
YOU HAVE ONLY 50 DOLLARSTHE NUMBER WAS 6
WOULD YOU LIKE TO BET AGAIN? ANSWER Y OR N
*Y

YOU NOW HAVE    50 DOLLARS
WHAT TYPE OF BET ARE YOU MAKING ?
*2
HOW MUCH MONEY DO YOU BET?
*25
YOU HAVE DECIDED TO BET ON 2 NOS.PLEASE NOTE:YOU MAY NOT BET ON ZERO
YOUR FIRST NUMBER IS:
*26
AND YOUR SECOND NUMBER IS:
*11
ALL RIGHT, LET'S SEE HOW YOU DID. THE NUMBER WAS 20
SORRY BUT YOU CANT WIN THEM ALL
```

205

```
YOU NOW HAVE ONLY  25 DOLLARS
WOULD YOU LIKE TO BET AGAIN? ANSWER Y OR N
*Y

YOU NOW HAVE   25 DOLLARS
WHAT TYPE OF BET ARE YOU MAKING ?
*5
HOW MUCH MONEY DO YOU BET?
*15
```

$$\cdots$$

The ROULETTE procedure for this extended version is several
pages long. It probably represents the most concerted,
intense, and lengthy intellectual enterprise the student has
entered on in his entire career to date.

(5) After School

As a final illustration, the following much simpler project
again shows the relevance of LOGO to a student's battles and
burdens. It is an application to a classic school problem.
The student came with a question: "Can you help me write a
procedure that will print 'I will never throw a book out of
the window again' 200 times?"

In point of fact, a formally identical procedure had been
discussed in class sometime earlier. This was the procedure
TO LAFF.

```
 TO LAFF /NTIMES/
>10 TEST IS /NTIMES/ 0
>20 IF TRUE STOP
>30 PRINT "HA HA HO HO HEE HEE HEH HEH YAH!!!!!"
>40 LAFF DIFFERENCE OF /NTIMES/ AND 1
>END
LAFF DEFINED
→
```

Its effect is:

```
 LAFF 4
HA HA HO HO HEE HEE HEH HEH YAH!!!!!
HA HA HO HO HEE HEE HEH HEH YAH!!!!!
HA HA HO HO HEE HEE HEH HEH YAH!!!!!
HA HA HO HO HEE HEE HEH HEH YAH!!!!!
```

The student was reminded of this procedure. He understood its
relevance to his problem. He had previously looked at LAFF
and run it, but he had never really thought about how it
worked. Now he had a good reason to do so. After a considerable
effort he wrote the following procedure (the name SWEAR-OFF
was not his own; it was suggested to him).

```
TO SWEAR-OFF /NTIMES/
>10 TEST IS /NTIMES/ 0
>20 IF TRUE STOP
>30 PRINT "I WILL NEVER THROW A BOOK OUT OF THE WINDOW AGAIN"
>40 SWEAR-OFF DIFFERENCE OF /NTIMES/ AND 1
>END
SWEAR-OFF DEFINED
```

He tried it, and it worked!

```
 SWEAR-OFF 200
```

```
I WILL NEVER THROW A BOOK OUT OF THE WINDOW AGAIN
I WILL NEVER THROW A BOOK OUT OF THE WINDOW AGAIN
I WILL NEVER THROW A BOOK OUT OF THE WINDOW AGAIN
I WILL NEVER THROW A BOOK OUT OF THE WINDOW AGAIN
I WILL NEVER THROW A BOOK OUT OF THE WINDOW AGAIN
I WILL NEVER THROW A BOOK OUT OF THE WINDOW AGAIN
I WILL NEVER THROW A BOOK OUT OF THE WINDOW AGAIN
I WILL NEVER THROW A BOOK OUT OF THE WINDOW AGAIN
I WILL NEVER THROW A BOOK OUT OF THE WINDOW AGAIN
I WILL NEVER THROW A BOOK OUT OF THE WINDOW AGAIN
I WILL NEVER THROW A BOOK OUT OF THE WINDOW AGAIN
                .           .           .
                .           .           .
                .           .           .
```

207

Though it was not likely that the offended teacher would
accept this print-out as satisfying the assignment in a
bona-fide way, the student was lucky. When he turned in the
print-out, the teacher was absent and it was accepted by the
substitute!

The student was ready for a related assignment at this point.
He was asked if there was some likelihood that he might be
given a similar after-school task again. He allowed as
possible that he might. To save extra work, then, it was
suggested that he write a two-input procedure:
TO COPY /ANYTHING/ /N TIMES/.
Its effect would be to do what it seemed to say. For example,
COPY "I'LL NEVER SLEEP IN CLASS" 1000
would print the sentence "I'LL NEVER SLEEP IN CLASS", 1000
times.

With a great deal of help he wrote the following procedure:

```
TO COPY /ANYTHING/ /NTIMES/
10 TEST IS /NTIMES/ "0"
20 IF TRUE STOP
30 PRINT /ANYTHING/
40 COPY /ANYTHING/ DIFFERENCE OF /NTIMES/ AND "1"
END
```

His first use of it was as follows:

```
→COPY "I'M THE GREATEST" 9999
I'M THE GREATEST
I'M THE GREATEST
I'M THE GREATEST
I'M THE GREATEST
I'M THE GREATEST
I'M THE GREATEST
I'M THE GREATEST
I'M THE GREATEST
I'M THE GREATEST
  .      .      .
  .      .      .
  .      .      .
```

4.2.4 Conclusions

Our students had a history which showed enormous resistance to doing formal academic work. It was clear from the start that LOGO provided a means of overcoming their resistance. Working with computers was seen by them as "a good thing", just like shop and gym. Our problem was to find ways of using LOGO to help in articulating their difficulties, and introducing them to formal thinking and problem-solving.

Most of the students were interested in using LOGO at two distinct levels of involvement. First, they simply liked to work at the computer terminal. What they were doing there was not always important; indeed, the students often were quite happy doing routine, tedious, repetitive, mechanical tasks assigned to them so long as they could do these interactively at the terminal. In carrying out this assigned work, including much of the lesson material, they did not always find it important to *think about* what they were doing. They simply liked to do it, just as they liked doodling or running. Their compelling interest in using the machine continued throughout the three-month period, from start to finish. During this course of time, they gradually acquired the formal material covered in the lessons.

Any kind of work at the terminal, however trivial, was far preferable to the students to any kind of standard classroom work (not only like listening to lectures but also even participating in small informal group discussions - so long as these were organized and directed toward a goal which the students had not themselves set).

the other and deeper level of involvement came from working on
their own projects.   There were three sources of such projects:
(1) some projects came out of what the students perceived as
real, personal problems (for example, those discussed in the
paragraphs Affidavit and After School in Section 4.2.3), (2)
some were expressions of protest directed at the school establish-
ment (for example, the PASS procedures discussed above in Rights
of Passage), and (3) some developed out of activities and games
they already were interested in (such as the projects discussed
under Drawing and Roulette).

The real possibilities for breaking through the students' resist-
ance to formal ways of thinking was evidenced in their work on
these various projects.

Students were beginning to have resources adequate for doing
projects on their own by the end of the course. There was too
little time available to carry out very many projects genuinely
expressive of their own efforts. But we do have a few protocols
from projects of this kind. Moreover, we think the particular
projects that were developed can be advantageously incorporated
in a general problem-solving curriculum.

These conculsions are impressionistic. We also performed some
evaluation of an "objective" sort. We were reasonably sure that
the standard use of achievement testing would not show significant
changes of the kind we were observing. As a result of thinking
about the difficulties of measuring changes in performance
(particularly for students like the ones involved in our teaching
experiment), we designed and carried out a testing experiment
which is described in the next section.

4.3 EXPERIMENT ON TEST VALIDITY

4.3.1 Rationale and Design

In carrying out the teaching experiment just described, we were
mainly interested in the use of LOGO for studying problem-solving.
We also had some interest in assessing the side effects of this
teaching on the reading skills of our students. All six students
were very deficient in reading comprehension and vocabulary.
Their reading levels consistently measured from three to as much
as five years below their current (eighth) grade level. Previous
remedial reading instruction had not improved their skill in read-
ing very much.

Our conjecture was that their work with LOGO programming might
be a means of significantly helping their reading. We expected
that they would be very willing to read a great deal of material
at the teletype, including the voluminous text printouts in the
series of 24 LOGO lessons (particularly if this was a necessary
part of learning to use the computer, which they wanted so much
to do). Further, the requirements of reading and writing programs
are exacting, and demand careful attention to the meanings of
words and sentences and their formal relationships in expressions,
instructions, and procedures. Thus, since the programming tasks
were interesting and often self-selected, and since doing them
imposed attention to, and concentration on, reading, we looked
for some improvement in reading skill to come out of this
approach vis-a-vis LOGO.

However, we did not expect that we would be able to measure
significant gains in reading over the relatively short time span
(about three months) of the experiment. We expected we would

have to make a judgment as to the potential benefits from using
LOGO as a means of teaching reading based on indirect evidence,
from protocols, interviews, and anecdotes.

Nevertheless, we had planned to administer standard tests of
reading comprehension to our students, and to a comparable
"control" group, both before and after the teaching experiment.
And we did so, even though we expected very little from the tests.
Just before administering the reading post-tests, we were ruefully
considering the antipathy toward testing characteristic of our
students, which made it even more likely that (even the best)
reading tests would fail to adequately show the positive gradient
of their progress.

At this point we realized that, in the same sense that our students
did not give serious attention to official school work in the
classroom, they very possibly *did not take tests*. That is, the
way in which they addressed the task was open to question. We
surmised that their reading test scores did not adequately reflect
their actual achievement level (or, at least, the level at which
they currently were capable of performing). Moreover, we
conjectured that, if they were given the same reading test (or
an equivalent version) in the conventional written form and also
on the computer, they would do a great deal better on the computer
one.

We therefore extended our post-test design. We administered the
standard written form as well as an equivalent computer form
(which we had programmed in LOGO) to an expanded group of 61
students (which included our six students), in June. This group
included about twenty students with low reading scores on previous

212

tests and about forty with average or above average scores. We
expected all their scores to improve somewhat on the computer
test but that scores of certain of these students (who would then
be established as underachievers) would increase considerably.

We used for our testing the general reading section of the
Diagnostic Reading Test. This is described next.

4.3.2 Test Forms

An excerpt from the standard written form of the test we
implemented on the computer, including the directions given to
the subject, is reproduced next.

PART 1: GENERAL READING

DIRECTIONS: This is a test of your skill in general reading. Read the short article in this test in
the same way that you ordinarily read any easy, interesting stories or articles. Read as rapidly as you can
and still understand what you read. When you finish reading, you will be asked to answer questions on
the material you have read.

To start the test, everyone will read together the lines at the bottom of this page. The examiner will
read *orally* and you should follow, reading *silently*. When we come to the last word on the page, the
examiner will stop, and you will simply turn the page and keep right on reading.

After you have read for several minutes, the examiner will say "Mark."

IF THE ANSWERS ARE TO BE RECORDED IN THIS BOOKLET, put a circle around
the word you are reading when the examiner says "Mark." Then go right on reading.

IF THE ANSWERS ARE TO BE RECORDED ON SEPARATE ANSWER SHEETS, you
will use the place on the answer sheet labeled "Scores." On the separate *answer sheets* find space 1a.
under "Scores" and place a check mark there.   Note that each line of the reading selection is   num-
bered in the left-hand margin.   When the examiner says   "Mark," *write the number of the line you
are reading in Space* 1a under "Scores" on your *answer sheet.* After you have written this number, go
right on reading the article.

When you finish reading you will find printed directions telling you what to do next. DO NOT READ
ANY PART OF THE SELECTION MORE THAN ONCE.

If you have any questions about the directions, *ask them now;* if not, wait for the signal to turn to the
next page.

ANTS

1 Have you ever noticed how many ants there are in this world? It is
2 possible to find millions near your own home. They were on the earth long
3 before the first man appeared. Dr. John Martin, a scientist who has studied
4 ants, says that they have been here for fifty million years. He says that ants
5 have an organized society made up of queens, workers, and drones. The
6 workers are divided into policemen, guards, nurses and soldiers, so-called

:   :   :   .

135 If you observe ants for any length of time at all, you will see how
136 constantly they cross their antennae with those of other ants, obviously as
137 a means of communication. They distinguish foes from friends by reaching
138 out their antennae in challenge. They receive in the same way, a response
139 from those ants they meet. Two ants, foraging for food, always cross
140 antennae when they meet. Going or coming, leaving home or returning, on
141 the city premises or afield, it is always the same. The observer sees at once
142 from the ants' reactions to each other that everything is all right, and they
143 pass. Whether the message is conveyed by odor, by contact, or by both,
144 Dr. Martin and other scientists do not tell us, but that they do communicate
145 is readily apparent.

Turn to the next page without waiting for further directions.

Read the directions.

Mark the answers according to the directions.

After this rather lengthy article is read, the subject is given
twenty multiple-choice questions about it.

QUESTIONS ON *Ants*

DIRECTIONS: Read the statement. Choose the answer that agrees with the test selection you have
just read, even if you have a different opinion about it.

IF THE ANSWERS ARE TO BE RECORDED IN THIS BOOKLET, place the number of
the answer in the parentheses at the right. Study the following example:

Sample: The color of grass is

(1) green   (2) blue   (3) purple   (4) orange. . . . . . . (1)

IF THE ANSWERS ARE TO BE RECORDED ON SEPARATE ANSWER SHEETS, make a heavy, black, *glossy mark* on the answer sheet under the number that agrees with the number of the answer you chose. Use the special pencil which your examiner gave you. Study the following example:

Sample: The color of grass is

(1) green (2) blue (3) purple (4) orange

Notice the space under number one has been marked because the correct answer, green, has that number.

Do NOT go back to the reading selection.

1. The ants have a society similar to

   (1) a republic .... ( )
   (2) a democracy .... ( )
   (3) a monarchy .... ( )
   (4) an army .... ( )

2. According to the story, the wedding of ants may take place in

   (1) January .... ( )
   (2) October .... ( )
   (3) April .... ( )
   (4) July .... ( )

3. The number of eggs that a queen lays in her lifetime is

   (1) between five hundred and a thousand .... ( )
   (2) one every two weeks .... ( )
   (3) less than five hundred .... ( )
   (4) more than one million .... ( )

$$\vdots \quad \vdots \quad \vdots$$

19. From reading the story we can conclude that

    (1) the government is administered by the soldier ants .... ( )
    (2) ants have a democratic form of government .... ( )
    (3) ants have an organized society .... ( )
    (4) ants are more helpful than is generally believed .... ( )

20. If you were to write a story about the ants, which of the following would you leave out because we know least about it?

    (1) food and living conditions of ants .... ( )
    (2) kinds of ants .... ( )
    (3) governmental organization .... ( )
    (4) special language of ants .... ( )

Our subjects took this test form, not as a standard written
test, but as an interactive quiz at a computer terminal. In
the first part of the computer test, they read the article
above, as it was spewed out in a series of short fragments.
Subjects controlled the rate at which successive fragments
were typed out. To get the next fragment, the subject merely
hit a key on the teletype when he was ready for it. The
program introduced double-spacing between fragments. An
excerpt from the first part of the test, including the
instructions to the subject, follows.

```
PLEASE TYPE YOUR NAME AND THEN PRESS THE KEY MARKED RETURN
*ROSANNE DILUNA
THIS IS A READING QUIZ.
FIRST YOU WILL READ AN ARTICLE ON ANTS.
THEN YOU WILL BE GIVEN SOME QUESTIONS ABOUT THE ARTICLE.
THE COMPUTER WILL TYPE THE ARTICLE OUT FOR YOU TO READ IN PARTS, A
SENTENCE OR TWO AT A TIME.
AFTER EACH PART, IT WILL TYPE THIS SPECIAL MARK @.
THEN IT WILL WAIT FOR YOU TO READ THAT PART.
WHEN YOU ARE FINISHED READING THE PART, PRESS THE KEY MARKED RETURN.
THEN IT WILL TYPE OUT THE NEXT PART.
LET'S TRY THAT NOW. WHEN YOU SEE THE SPECIAL MARK, HIT THE RETURN KEY
AND WE WILL BEGIN. @
*

HAVE YOU EVER NOTICED HOW MANY ANTS THERE ARE IN THIS WORLD? IT IS
POSSIBLE TO FIND MILLIONS NEAR YOUR OWN HOME.@
*

THEY WERE ON THE EARTH LONG BEFORE THE FIRST MAN APPEARED. DR. JOHN
MARTIN, A SCIENTIST WHO HAS STUDIED ANTS, SAYS THAT THEY HAVE BEEN HERE
FOR FIFTY MILLION YEARS.@
*

HE SAYS THAT ANTS HAVE AN ORGANIZED SOCIETY MADE UP OF QUEENS, WORKERS,
AND DRONES. THE WORKERS ARE DIVIDED INTO POLICEMEN, GUARDS, NURSES AND
SOLDIERS, SO-CALLED ACCORDING TO THE TYPE OF WORK THEY DO.@
*

THE QUEEN ANT IS THE RULER AND THE MOST IMPORTANT MEMBER OF THE ANT
HILL. HER WEDDING DAY IS AN EXTREMELY IMPORTANT DAY FOR THE QUEEN, AND
THE ACTIVITIES OF THAT DAY ARE INTERESTING TO WATCH.@
*

THE WEDDING TAKES PLACE IN THE SPRING OF THE YEAR ON A WARM SUNSHINY
DAY. ALL OF THE QUEENS AND THE FATHER ANTS, CALLED DRONES, LEAVE THEIR
ANT HILLS. FOR A WHILE THEY STAY ON THE GROUND.@
*           .           .           .
            .           .           .
            .           .           .
```

IF YOU OBSERVE ANTS, FOR ANY LENGTH OF TIME AT ALL, ,YOU WILL SEE HOW
CONSTANTLY THEY CROSS THEIR ANTENNAE WITH THOSE OF OTHER ANTS,
OBVIOUSLY AS A MEANS OF COMMUNICATION.@
*

THEY DISTINGUISH FOES FROM FRIENDS BY REACHING OUT THEIR ANTENNAE IN
CHALLENGE. THEY RECEIVE IN THE SAME WAY, A RESPONSE FROM THOSE ANTS
THEY MEET. TWO ANTS, FORAGING FOR FOOD, ALWAYS CROSS ANTENNAE WHEN THEY
MEET.@
*

GOING OR COMING, LEAVING HOME OR RETURNING, ON THE CITY PREMISES OR
AFIELD, IT IS ALWAYS THE SAME. THE OBSERVER SEES AT ONCE FROM THE ANTS'
REACTIONS TO EACH OTHER THAT EVERYTHING IS ALL RIGHT, AND THEY PASS.@
*

WHETHER THE MESSAGE IS CONVEYED BY ODOR, BY CONTACT, OR BY BOTH, DR.
MARTIN AND OTHER SCIENTISTS DO NOT TELL US, BUT THAT THEY DO
COMMUNICATE IS READILY APPARENT.@
*

Following the administration of this subject-paced reading

phase of the test, the computer gave the twenty multiple-

choice questions, to the subject, in sequence.

6/15/1970
2:16 PM
ROSANNE DILUNA
HERE ARE 20 QUESTIONS ABOUT THE ARTICLE ON ANTS. READ EACH STATEMENT
CAREFULLY. THEN TYPE THE NUMBER OF THE ANSWER THAT AGREES WITH THE
ARTICLE, EVEN IF YOU HAVE A DIFFERENT OPINION ABOUT IT. THEN PRESS THE
RETURN KEY. HERE IS A SAMPLE QUESTION.@
*

THE COLOR OF RED WINE IS

        1 BLUE

        2 GREEN

        3 RED

        4 WHITE

*3
GOOD. NOW LET'S GO ON TO THE QUESTIONS ABOUT ANTS.
ANSWER EACH QUESTION AS WELL AS YOU CAN. YOU WILL BE ABLE TO CHANGE
SOME ANSWERS LATER IF YOU WISH.

217

1. THE ANTS HAVE A SOCIETY SIMILAR TO

    1 A REPUBLIC

    2 A DEMOCRACY

    3 A MONARCHY

    4 AN ARMY

TYPE THE NUMBER OF THE ANSWER YOU THINK RIGHT. (TYPE THE NUMBER 0 IF
YOU WANT TO SKIP THE QUESTION UNTIL LATER)
*3

2. ACCORDING TO THE STORY, THE WEDDING OF ANTS MAY TAKE PLACE IN

    1 JANUARY

    2 OCTOBER

    3 APRIL

    4 JULY

TYPE THE NUMBER OF THE ANSWER YOU THINK RIGHT. (TYPE THE NUMBER 0 IF
YOU WANT TO SKIP THE QUESTION UNTIL LATER)
*1

3. THE NUMBER OF EGGS THAT A QUEEN LAYS IN HER LIFETIME IS

    1 BETWEEN FIVE HUNDRED AND A THOUSAND

    2 ONE EVERY TWO WEEKS

    3 LESS THAN FIVE HUNDRED

    4 MORE THAN ONE MILLION

TYPE THE NUMBER OF THE ANSWER YOU THINK RIGHT. (TYPE THE NUMBER 0 IF
YOU WANT TO SKIP THE QUESTION UNTIL LATER)
*4

           .   .   .
           .   .   .
           .   .   .

19. FROM READING THE STORY WE CAN CONCLUDE THAT

     1 THE GOVERNMENT IS ADMINISTERED BY THE SOLDIER ANTS

     2 ANTS HAVE A DEMOCRATIC FORM OF GOVERNMENT

     3 ANTS HAVE AN ORGANIZED SOCIETY

     4 ANTS ARE MORE HELPFUL THAN IS GENERALLY BELIEVED

TYPE THE NUMBER OF THE ANSWER YOU THINK RIGHT. (TYPE THE NUMBER 0 IF
YOU WANT TO SKIP THE QUESTION UNTIL LATER)
*3

20. IF YOU WERE TO WRITE A STORY ABOUT THE ANTS, WHICH OF THE FOLLOWING
WOULD YOU LEAVE OUT BECAUSE WE KNOW LEAST ABOUT IT?

     1 FOOD AND LIVING CONDITIONS OF ANTS

     2 KINDS OF ANTS

     3 GOVERNMENTAL ORGANIZATION

     4 SPECIAL LANGUAGE OF ANTS

TYPE THE NUMBER OF THE ANSWER YOU THINK RIGHT. (TYPE THE NUMBER 0 IF
YOU WANT TO SKIP THE QUESTION UNTIL LATER)
*4

    After this, the subject could reconsider specific questions
    and change his answers, if he so desired.

DO YOU WANT TO CHANGE YOUR ANSWER TO SOME QUESTION? (PLEASE TYPE YES IF
YOU DO)
*YES
WHICH QUESTION? (TYPE THE NUMBER OF THE QUESTION)
*2
WHAT WOULD YOU LIKE TO CHANGE YOUR ANSWER TO ? (TYPE A NUMBER BETWEEN 1
AND 4)
*3

DO YOU WANT TO CHANGE YOUR ANSWER TO SOME OTHER QUESTION?
*NO.

Our subjects took this computer test and also a standard written
version of the General Reading Test. The written test used an
equivalent form, about coyotes, (Form B) rather than ants, (Form
D). Approximately half the subjects took the computer version
before the written one. Most of the testing was done during the
period June 10 - 16, 1970.

4.3.3 Results

The next two pages list the results of our testing, along with
associated test data. The subjects are grouped according to IQ
score range. The individual IQ scores (Stanford-Binet scores
mostly administered when the subjects were second-graders) for
each subject are listed opposite the subject's identification
number. Associated test scores for the comprehension part of the
Gates-MacGinitie Reading Test, which was given in 1969 and again
in 1970, are listed under the column entries G-M (69) and G-M (70).

In the final three columns we have listed the general reading
scores from the various forms of the Diagnostic Reading Test.
The first column, labeled DRT (A) lists the score obtained on
the Form A version of the test. This was a written form of the
test that had been administered to several subjects some months
before our testing effort. This test score and the Gates-
MacGinitie scores are listed primarily to show the general
stability and consistency of previous reading scores for most
subjects. The last two columns give the scores obtained from
our testing. Under DRT (B) are listed the scores obtained on
the Form B version - given as a written test. Under DRT (D)
are listed the scores obtained on the equivalent Form D version
of the test - the one administered on the computer. The DRT
entries are raw scores in the range $0 - 20$. The Gates-MacGinitie
entries, on the other hand, are grade levels obtained from
normalized raw scores.

220

Reading Scores by Subject

IQ RANGE	SUBJECT	IQ	G-M (69)	G-M (70)	DRT (A)	DRT (B)	DRT (D)
70-89	1	76	3.4	4.1	5	8	9
	2	87	3.6	4.1	5	4	8
	3	86	4.3	4.8	8	7	9
	4	88	5.1	4.1	6	6	10
	5	82	6.2	7.8	5	12	11
	6	86	3.5	5.5	4	10	11
90-99	7	96	5.3	6.5		5	9
	8	97	4.5	5.5		10	13
	9	99	?	6.7	5	5	15
	10	?	3.6	4.8		6	11
	11	93	7.8	7.2		10	15
	12	94	8.6	7.8		10	14
	13	98	8.6	7.8		11	11
	14	99	7.8	6.2		9	9
100-109	15	105	5.8	6.0		17	13
	16	107	3.9	2.7		2	12
	17	101	8.9	7.2		12	9
	18	107	8.4	9.2		12	14
	19	108	8.6	9.6		18	14
	20	109	8.9	8.4		15	17
	21	109	8.9	9.6		18	11
	22	106	4.3	8.6		10	13
	23	105	4.5	8.2		12	13
	24	102	6.2	8.9		14	6
	25	108	8.2	3.7		18	15
110-119	26	110	3.7	4.8		5	17
	27	114	3.2	4.8	7	8	7
	28	117	2.8	2.6	1	2	11
	29	116	6.0	3.9	3	9	10
	30	111	6.0	5.5		13	10

Reading Scores by Subject (Cont.)

IQ RANGE	SUBJECT	IQ	G-M (69)	G-M (70)	DRT (A)	DRT (B)	DRT (D)
110-119	31	111	5.1	3.6		10	14
	32	113	7.2	4.1	6	6	13
	33	110	8.9	10.4		13	8
	34	115	9.2	10.9		17	12
	35	116	8.9	9.2		11	9
	36	117	8.6	10.0		14	10
	37	119	9.2	10.4		12	13
	38	111	4.3	9.6		8	10
	39	115	5.3	7.6		10	15
	40	115	5.8	7.6		13	9
	41	116	6.2	7.8		9	10
	42	117	7.8	2.7		8	9
	43	117	12.9	3.1		18	17
120-129	44	126	3.1	3.1		14	7
	45	122	6.2	5.8	3	4	14
	46	127	4.3	7.0		13	16
	47	121	9.6	9.6		12	11
	48	122	8.9	8.9		14	13
	49	125	8.9	10.0		17	14
	50	127	5.5	8.9	7	11	15
	51	122	5.3	9.2		15	15
	52	120	6.7	8.2		8	9
	53	121	6.2	7.8		13	8
130-	54	131	8.2	11.4		16	12
	55	132	9.2	10.9		18	16
	56	136	8.9	10.9		9	13
	57	140	9.2	10.9		16	16
	58	130	8.4	8.6		11	14
	59	133	7.2	9.2		18	15
	60	142	6.7	8.6		3	15
	61	144	7.4	9.2		14	17

We have just started to analyze these data. Our preliminary results are presented in the form of contingency tables. The first of these (TABLE 1) shows the various computer scores (from the Form D test) corresponding to a given written score (from the Form B test). Thus, the two entries under the column labeled 2 indicate two subjects who got scores of 2 on the written test and whose computer test scores were 12 and 11, respectively.

TABLE 2 shows the pairs of scores arranged the opposite way, that is the written test scores corresponding to a given computer test score. Finally, TABLE 3 shows the scores paired according to the time sequence in which the two tests were given, that is the scores obtained on the second test that was taken (whether in the written or computer version) corresponding to a given score on the first test taken.

Associated with each table is a summary giving average changes within each septile range of scores. For each range we have listed the number of scores (N), the sum of the computer test scores ΣD, and the mean computer score $\overline{D}$, and the sum of the written test scores ΣB, and the mean written test score $\overline{B}$, (except in TABLE 3 where we have the sums for the first and second scores ΣF, ΣS and the associated means $\overline{F}$, $\overline{S}$), and, finally, the difference between the two mean scores.

The most striking result is the great improvement in computer test scores achieved by subjects who had low scores on the written test. (See $\overline{D}-\overline{B}$ for the first two septiles in TABLE 1.) This change appears to be significant. We are currently checking its significance, taking into account the standard regression toward the mean effect associated with bounded tests such as this one (which has only twenty questions).

223

The improvement of low-scorers is strictly in the one direction: there is no comparable effect observable in TABLE 2. In fact, there were no subjects who actually got very low (in the first two septile ranges) computer scores. Moreover, TABLE 3 does not confirm the possibility that there is a large improvement obtained on the second test, independently of which one it is. (It might have been true that people simply did better the second time around.)

A second result of interest is that moderately high and high scorers on the written test did less well in their scores on the computer test. This was contrary to expectation. We think this result will not be entirely explained by the regression toward the mean effect, either.

One way of summarizing our tentative results is: the standard written form of the test does not adequately assess the performance level (or at least the potential performance level) of low-scorers. (An incidental and important point: only about half of the low-scorers were members of our experimental computer class. Moreover, some of the low-scorers probably were "classical" underachievers but some were probably not.) While casting some doubt on the validity of standard test assessment of low achieving readers, our results support a relatively practical way to remedy this problem -- by simply retesting low-scorers on a computer form of the standard reading test.

We expect to complete the analysis of these data shortly and we then plan to submit this material for publication in an appropriate testing journal such as Psychometrika.

224

CONTINGENCY TABLE 1
Paper Test (Form B) versus Computer Test (Form D)

B	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
D	12	15	8	9	10	9	9	10	13	11	11	10	7	17	12	13	14
	11		14	15	11		7	9	14	9	9	16	10	15	16	12	11
				17	13		10	13	15	15	14	8	13			14	16
							9	10	14	14	13	9	6				15
							9		11		11	8	17				17
									13		13						15
									15								

Average Changes within Each Septile of Range

Septile	0-2	3-5	6-8	9-11	12-14	15-17	18-20
N	2	6	9	15	16	7	6
ΣD	23	78	87	186	175	99	88
ΣB	4	33	65	150	207	113	128
$\overline{D}$	11.5	13.0	9.7	12.4	10.9	14.1	14.7
$\overline{B}$	2	5.5	7.2	10.0	12.9	16.1	18.0
$\overline{D}-\overline{B}$	9.5	7.5	2.5	2.4	-2.0	-2.0	-3.3

CONTINGENCY TABLE 2
Computer Test (Form D) Versus Paper Test (Form B)

D	6	7	8	9	10	11	12	13	14	15	16	17
B	14	8	4	8	6	6	2	10	10	5	13	5
		14	13	7	9	2	17	17	4	10	18	15
			13	5	13	12	16	6	10	18	16	18
				9	14	11		12	12	10		14
				12	8	18		14	18	11		
				11	9	12		9	17	15		
				13		10		10	11	18		
				8				12		3		
				8								

Average Changes within Each Septile of Range

Septile	0-2	3-5	6-8	9-11	12-14	15-17	18-20
N	0	0	6	22	18	15	0
ΣB	--	--	66	211	207	189	--
ΣD	--	--	44	218	238	236	--
$\overline{B}$	--	--	11.0	9.6	11.5	12.6	--
$\overline{D}$	--	--	7.3	9.9	13.2	15.7	--
$(\overline{B}-\overline{D})$	--	--	3.7	-0.3	-1.7	-3.1	--

226

CONTINGENCY TABLE 3
First Test (F) versus Second Test (S)

F	2	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
S	11	8	15	10	9	9	5	13	6	2	10	10	17	13	5	14
		14		13	14	7	10	15	11	11	17	10	18	12	12	11
				14			9	14	9	9	8	13	10	16	14	16
						13	13	11	12	14	10	11	15		18	15
							13	8	15	13	12	17	3			
							8	9								

Average Changes within Each Septile Range*

Septile	6-8	9-11	12-14	15-17
N	9	17	15	12
Σ S	98	181	167	153
Σ F	64	169	195	191
$\bar{S}$	10.9	10.6	11.1	12.8
$\bar{F}$	7.1	9.9	13.0	15.9
$\bar{S}-\bar{F}$	3.8	0.7	-1.9	-3.1

* The ranges 0-2, 3-5, and 18-20 which contained 1, 3, and 4 cases respectively were excluded since in all these cases the computer test was given after the written test.

4.4 A COMPUTER-CONTROLLED VEHICLE FOR USE IN TEACHING
     PROBLEM-SOLVING

4.4.1 Engineering

The vehicle, whose preliminary design was described in the
previous technical report, is now being implemented. A
photograph showing its current appearance is included as
Figure 1. As can be seen from the figure, the vehicle has
the general shape of a turtle and, in fact, is now known by

Figure 1
The LOGO Turtle

The turtle is remote-controlled via a standard model-aircraft
transmitter-receiver system. The transmitter operates by
imposing one of six audio tones on an R. F. Carrier of
approximately 100 milliwatts. This system allows the turtle
to receive one of six possible function control signals at a

228

time. Presently, the functions being used are:

1. Forward
2. Backward
3. Rotate Right
4. Rotate Left
5. Beep Horn
6. Unused

The computer may initiate any one of these functions by sending
the appropriate character to the transmitter control circuit
(TCC), which in turn selects the signal to be transmitted to the
turtle. The effective indoor range of the transmitter is approx-
imately 50 feet.

The TCC determines the type and duration of the various functions
of the turtle. It contains logic and the analog controls to
adjust the significance of each of the control signals sent to
the turtle. The turtle makes its movements in fixed units of
distance or rotation: one unit forward or backward is approx-
imately four inches; one unit of rotation is currently 45 degrees.
These distances are adjustable over a considerable range, several
hundred percent, and the controls are mounted on the TCC. This
control is achieved through time-delay circuitry and has been
found to be capable of sufficient accuracy to obviate the need of
sensors in the turtle which would determine the distance traveled.
The TCC also has facilities for a manual control function selector.
This enables the operator to position the turtle by means of a
push-button control box. The box may function in two modes. In
the first mode, the operator simply pushes the relevant button for
a very short time, and the turtle responds by executing a movement
of one unit of motion in the appropriate direction. This is
called unit mode. The second manual control option (which is

229

switch selectable) allows the operator complete control of the
turtle by eliminating the time-delay circuitry of the TCC. In
this mode, the turtle will execute the selected function for as
long as the operator holds the button.

In the current state of the TCC, the commands from the computer
are translated for use by the TCC by the use of "function
switches" physically mounted inside the controlling teletype.
There are several of these switches, each must be specifically
coded to operate switch contacts when the particular character
is received. This is a drawback in the sense that for remote
use of the turtle, it would be necessary to carry the controlling
teletype with the turtle and arranging for appropriate hookup
facilities at the remote location. Work is now in progress on
the design and construction of a general-purpose turtle inter-
face which would allow use of the turtle with virtually any
teletype. This interface will contain a teletype receiver and
character decoder which will function independently of direct
hookup to the teletype and needs only access to the information
line. This interface will be able to recognize signals intended
for control of the turtle and initiate their execution.

The turtle itself contains a receiver capable of determining
which function was transmitted by the transmitter control circuit.
It uses this signal to operate one of six control relays. Mechan-
ically, the turtle consists of a one-foot diameter circular plate
with two motor-driven wheels mounted on one of the central axes,
see Fig. 1.

The turning functions are achieved by complementing the sense of
the motors, i.e., one motor is powered to go forward while the
other motor is powered to go in reverse. This method of turning

control permits the turtle to rotate at its center to accomplish
its turns. By rotating about its vertical axis, it is not
necessary to include turning radius factors in the computation
of course to get from one point to another. The turtle has an
effective braking system. The brakes are engaged whenever the
turtle is not in the process of executing one of its motion
functions. The brakes are turned off upon receipt of one of the
motion functions from the TCC, and are applied again as soon as
the receiver detects that the signal is gone. Thus, there is no
"coasting" of the turtle which might introduce inaccuracies in the
motion of the vehicle. Power for the turtle is currently supplied
by dry cell (non-rechargeable) batteries, but it will soon be
powered by nickel-cadmium (Ni-Ca) cells which are expected to
permit several hours of use between recharges.

The turtle will contain a transmitter with which it can send
information back to the computer. This transmitter is similar
to the one used to control the turtle, but operating on a
different frequency. Bumpers will be provided for the turtle so
that a signal may be sent to the computer if the turtle encounters
an obstacle. The bumpers will be placed such that it will be
possible to determine which section (quadrant) of the turtle hit
the obstacle. The programmer can then use this information to
alter or affect his program. There will be facilities for the
implementation of several other types of sensors in the vehicle,
for example, a light sensor (a photocell) or a path-following
mechanism. The inclusion of two-way communication makes it
possible to richly expand the realm of uses for the system by
enabling adaptive programming of problem-solving tasks of many
kinds.

4.4.2 Program Control

There are currently two languages which can be used to control
the turtle. The first is an abbreviated command language, written
and used primarily for debugging the turtle. Commands in this
language are expressed as a string of digit-letter pairs in which
the letter is used to designate the function to be performed,
while the digit is used as a count of the number of times the
function is to be executed. (The four functions for moving the
turtle are designated F, B, R, L for forward, backward, right,
and left, respectively.) For example, the string 6F2R2B1L would
cause the turtle to go six units forward, then turn two units to
the right, back up two units, then turn one unit to the left.
In this language there are two other legal function designations:
H, which causes the horn to beep the designated number of times,
and " (a ditto mark) which calls for a complete command string
to be repeated the designated number of times. An example using
these is: 2R1H2F3". This instructs the turtle to describe a
square (beeping it's horn at each corner). During the execution
of each digit-letter pair of the command string, the teletype
types out the command being executed so the user may see what is
being done.

The second control language uses five new commands implemented in
the LOGO language for this purpose. The commands are: right,
left, front, back, and horn. Each of these commands takes a
number with it which determines the number of units to be
executed. An example of a LOGO program using right and front to
describe a square is,

```
TO SQUARE /X/
1Ø RIGHT "2"
2Ø FRONT /X/
3Ø SQUARE /X/
END
```

232

In this program the size of the square to be traversed by the
turtle is determined by the value of X in the input /X/. The
turtle makes a 90° turn (Right 2), goes forward /X/ times, and
then repeats the whole process. The square program can be
modified to make a "spiral" procedure by having LOGO reduce (or
increase) the lengths of the straight legs each time through.
A LOGO program which causes the turtle to traverse an inward
spiral is

```
TO SPIRAL /X/
1Ø RIGHT "2"
2Ø FRONT /X/
3Ø SPIRAL DIFFERENCE /X/ "1"
END
```

This was the first procedure implemented to test the operations
of the five new turtle commands with LOGO. Another example
causes the turtle to simulate a familiar dance.

```
TO CHA-CHA
1Ø FRONT "2"
2Ø BACK "2"
3Ø LEFT "1"
4Ø RIGHT "1"
5Ø LEFT "1"
6Ø BACK "2"
7Ø FRONT "2"
8Ø RIGHT "1"
9Ø LEFT "1"
1ØØ RIGHT "1"
11Ø CHA-CHA
END
```

Another early procedure, not quite as straightforward as Cha-Cha,
is the Random Walk procedure which selects successive turtle
commands randomly and performs each command some randomly-
determined number of times.

233

```
TO RANDOM-WALK
1 MAKE                            (Changes a random digit in the
   NAME:  "X"                      range 0 thru 9 to a random
   THING:   SUM OF RANDOM AND 1    number from 1 thru 10)
2 TO TO LINE WORD /X/ "Ø"         (If the number was 1, control
                                   goes to instruction line 1Ø;
                                   if 2 to line 2Ø; ... if 1Ø to
                                   line 1ØØ)

1Ø FRONT RANDOM
15 RANDOM-WALK
2Ø FRONT RANDOM
25 RANDOM-WALK
3Ø BACK RANDOM
35 RANDOM-WALK
4Ø BACK RANDOM
45 RANDOM-WALK
5Ø LEFT RANDOM
55 RANDOM-WALK
6Ø LEFT RANDOM
65 RANDOM-WALK
7Ø RIGHT RANDOM
75 RANDOM-WALK
8Ø RIGHT RANDOM
85 RANDOM-WALK
9Ø HORN RANDOM
95 RANDOM-WALK                    (After each instruction is
1ØØ HORN RANDOM                    executed, the whole process is
1Ø5 RANDOM-WALK                    repeated by calling RANDOM-WALK
END                                again)
```

Additional commands will be added to LOGO as corresponding
functions are implemented in the turtle hardware. We shortly
plan to add the first sensor functions, a pair of bumpers for
detecting contact with obstacles touching on either side of the
turtle.

5. STUDIES OF HUMAN MEMORY AND LANGUAGE PROCESSING

    5.1 ANNOTATED BIBLIOGRAPHY

    5.2 OVERVIEW

    5.3 REPORTS

235

5. STUDIES OF HUMAN MEMORY AND LANGUAGE PROCESSING

Allan M. Collins and M. Ross Quillian

5.1 ANNOTATED BIBLIOGRAPHY

Collins, A. M. and Quillian, M. R. Tripping Down the Garden
Path.

Two experiments were run to see how people revise a mistaken
interpretation in part of a sentence. A reaction-time task was
used where Ss decided whether a string of words was a sentence
or not. Among the sentences were some that were likely to be
misinterpreted at first (i.e., garden-path sentences). The
results supported the notion that people use a bottom-up pro-
cessing strategy rather than a top-down strategy. Apparently,
reprocessing in the garden-path sentences only involved those
words that were misinterpreted initially.

5.2 OVERVIEW

Computerized question-answering systems that converse in English
will probably be used for storing and retrieving military infor-
mation in the not-too-distant future. In this project, we are
conducting experiments on how humans perform aspects of these
tasks in order to aid the development of such computer systems.
Results to date have indicated how people categorize concepts
and use inferences in question-answering and how they construct
interpretations in comprehending text. These findings are being

utilized in a computer project that is developing a network for
storage of factual information and routines for conversing with
this network in English.

The research in this period centered on a problem that frequently
arises in language comprehension by computer. Because of the
multiple meanings of most words in natural language, it is com-
mon that a wrong interpretation is at first put on words or
phrases in part of a sentence. For example, in "The wagon wheels
across the desert" a person or computer is likely to interpret
"wagon" as a modifier and "wheels" as a noun initially. A
person usually sees his mistake and corrects it rather quickly,
but it is not clear what is the best way to handle this problem
in computers. The experiment investigated how people revise
their original interpretation in order to develop strategies for
handling this problem by computer. The results indicated that
people can reinterpret the sentence without reprocessing any
words other than the ones originally misinterpreted. Apparently,
people can locate by semantic or syntactic segmentation just
what words in the sentence have been misassigned, and at the
same time retain successful interpretations for other words or
phrases. In this respect people seem to use what is called in
computational linguistics a bottom-up processing strategy. This
result indicates that sentence processors should attempt to
interpret small segments of text first and build interpretations
of larger segments out of these smaller pieces.

There are three general advantages for the development of com-
puterized question-answering systems that derive from these
psychological experiments: (a) knowing how people process
natural-language information provides strategies for computer

237

programs to do the same processing (programmers now try to
analyze their own processing introspectively, which is quite
unreliable); (b) accessing information by its "associative"
semantic structure, as humans do, will make it unnecessary to
anticipate with an indexing scheme how the information will be
requested in the future; and (c) knowledge of human information
processing will guide development toward systems that interact
with man in the most efficient way.

5.3 REPORTS

The paper annotated above is included in this report immediately
after this page.

TRIPPING DOWN THE GARDEN PATH*

Allan M. Collins

M. Ross Quillian

Bolt Beranek and Newman Inc.
50 Moulton St.
Cambridge, Mass. 02138

ABSTRACT

The first experiment tested the hypothesis that people
revise a mistaken interpretation in part of a sentence by
returning to a point before the mistake and reprocessing the
sentence. Such a process would be akin to a top-down parsing
strategy in computational linguistics. To test this notion,
Ss were given a reaction-time (RT) task of deciding whether a
string of words was a sentence or not. Among the sentences
were some that were likely to be misinterpreted at first (i.e.,
garden-path sentences). The number of words between the mis-
take and the first word that could force a reinterpretation was
systematically varied, since on the hypothesis above, the inter-
vening words would be processed twice in garden-path sentences.
The results showed that, while garden-path sentences required
more processing, the intervening words were not reprocessed.
This result suggested that a bottom-up parsing strategy is used
by people. A second experiment tested whether it was necessary
to reprocess an inserted word whose meaning depended on the mis-
interpreted words in the garden-path sentences. Again, the
results were negative. Apparently reprocessing in the garden-
path sentences only involved those words that were misinterpreted
initially.

240

INTRODUCTION

A garden-path sentence is one in which the reader (or hearer) is likely to misinterpret the early part of a sentence, only to realize his mistake later on in the sentence. For example, in "The cherry blossoms during summer into full bloom," a person is likely at first to interpret "cherry" as a modifier and "blossom" as a noun. He recognizes his mistake sometime during his reading of the rest of the sentence. This mistake is usually easy for people to correct, but such mistakes are a serious problem in developing computer programs for processing natural language (Quillian, 1969). It would be quite useful in developing natural-language processors to find out how people revise their interpretations when they discover such a mistake. In particular this information may make it possible to compare the parsing strategy people use to computational parsing procedures.

The name for such sentences (i.e., garden-path sentences) relates to the notion that comprehension or syntactic analysis of sentences involves following a path through a decision tree of some kind. In this view, when the path turns out to be a cul-de-sac, people return to an earlier fork in the tree and try another path. This strategy has been built into what are called top-down parsers in computational linguistics [see, for example, Feldman & Gries (1968) for a discussion of top-down parsing]. Most top-down parsers that have been built consider all possible paths in parallel as they proceed through the decision tree, but they could as well proceed down the most likely path at each fork, as people apparently do.

In contrast, bottom-up parsers [also in Feldman & Gries (1968)] proceed by building interpretations locally within phrases and then

241

forming these pieces together into larger segments. These also
make mistakes either in interpreting within phrases or in combin-
ing phrases. Then just as in top-down parsers, it is necessary
to backtrack, but this may only involve reinterpreting a single
phrase or the way it combines with other phrases. In other words,
in a bottom-up parser, backtracking does *not* involve reprocessing
any phrases in the sentence after the misinterpretation unless they
themselves need to be reinterpreted.

We ran two experiments in order to determine how people re-
vise their original interpretation of garden-path sentences. The
task of the *S* was to decide whether a string of words shown on a
computer display (a CRT) was a sentence or not. The decision was
difficult because the non-sentences (e.g., "The apple trees picked
in autumn") looked like sentences. It was impossible to tell non-
sentences from sentences without analyzing the meaning to some
degree.

Among the sentences, half were of the garden-path variety and
half were not. There were two basic types of garden-path sentences.
The two types were labeled subject-verb and modifier-subject, de-
pending on the parts of speech of the two words in the fork where
the wrong path was likely to be taken. Thus, "The cherry blossoms
into full bloom" would be a subject-verb type and "The lion stands
lie inside rings" would be a modifier-subject type. In both
cases, the reinterpretation required a different parsing of the
sentence. The same two types, subject-verb and modifier-subject,
were used in the non-garden-path sentences. These two types were
chosen because in garden-path sentences each type initially ap-
pears to be the other type. Hence, there was no clue the *S* could
use to tell when he was being led down a garden path.

242

The first experiment was designed to test the hypothesis that a person revises his interpretation of a sentence by going back either to the beginning of the sentence or to the fork where he made the wrong turn, and reprocessing the sentence as would a top-down parser. On this hypothesis the interpretation that had failed previously would be avoided the second time through. To test this hypothesis, we constructed many different garden-path sentences of the two types, and varied the number of words between the fork and the first word that might force a reinterpretation. This was done by inserting one or two words in the sentences directly after the fork. These words were usually temporal or locative phrases and were constructed so as not to force a reinterpretation of the earlier words. A fairly typical example is "during summer" in "The cherry blossoms during summer into full bloom." Each sentence was shown to one group of Ss with no such inserted words, to a second group with one inserted word, and to a third group with two inserted words. The three groups of Ss, however, saw sentences of all three lengths intermixed.

We assumed that the inserted words would increase the time it took to read any sentence, whether it was a garden-path sentence or not. But for garden-path sentences, a strategy of going back and reprocessing the sentence should make it necessary to analyze the inserted words twice. Therefore, as the number of inserted words increased from 0 to 2, this hypothesis predicts a *greater* increase in reaction time (RT) for garden-path sentences than for non-garden-path sentences.

EXPERIMENT 1

Method

The 24 Ss were all BBN employees who had no knowledge as to
the nature of the experiment. The word strings were shown one at
a time on a cathode ray tube (CRT) display connected to a PDP-8
computer. The letters in the words were all upper case. The S
sat approximately two feet away from the screen. The word strings
varied in length from about 2 inches (5° visual angle) to 4 inches
(10°) on the screen. Before each string was shown, a warning dot
appeared for a half second in the center of the screen. Then, the
string came on for 5 sec, followed by a blank screen for 1 sec
before the next warning dot appeared.

The S responded by pushing the right-hand microswitch if he
thought the word string was a sentence, and the left-hand micro-
switch if not. His response did not alter the timing of the dis-
play, and he received no feedback. His response was recorded
only if it occurred at least 1 sec after the onset of the word
string but before the offset (i.e., if his RT was between 1 and
5 sec). This restriction was introduced because the clock on the
PDP-8 only counts up to 4 sec. This resulted in our throwing away
some longer (over 5 sec) times, but few, if any, shorter times
(under 1 sec). This restriction may have introduced a slight
artificial ceiling effect in the data for the longer sentence types.

There were 96 word strings shown to each S of which three-
fourths (72) were sentences. The S was told to expect this pro-
portion of sentences. Half the sentences were garden-path senten-
ces and half were non-garden-path sentences (36 of each kind).

Among both garden-path and non-garden-path sentences, there were two basic sentence structures used: the modifier-subject type was formed with an article, a modifier, a subject, a verb, and a two-word predicate, in that order; the subject-verb type was formed with an article, a subject, a verb, and a three-word predicate. Altogether, then, there were four different types of sentences. Examples of the four types are shown in Table 1, including those with additional phrases added.

As can be seen in Table 1, there were three different length versions for each sentence. Sentence length was varied by inserting either one or two words after the third word in each sentence. These inserted words usually formed a locative or temporal phrase and were always consistent with either interpretation of the key words in the garden-path sentences. Each S saw equal numbers of sentences of all three lengths and all four types, but not all Ss saw the same version of each sentence. There were three different groups of Ss. Each sentence was presented to one group without any insertion, to a second group with one word inserted, and to a third group with two words inserted. These different versions of each sentence appeared at the same position in the sequence of sentences for the different groups of Ss. In total, all three groups of Ss saw six sentences of each type for each different sentence length.

One-fourth of the word strings (24) were non-sentences. The non-sentences were constructed to look as much like sentences as possible. Some had two verbs ("The group meets every day gathers") and some had no verb ("The apple trees picked in the autumn"). Examples of these kinds of non-sentences were explained to Ss beforehand. Three different lengths of non-sentences were formed

245

Table 1

Illustrative Sets of Sentences in Experiment 1

Garden-Path Sentences	Words per String

Subject-verb-type

The cherry blossoms into full bloom	6
The cherry blossoms early into full bloom	7
The cherry blossoms during summer into full bloom	8

Modifier-subject type

The lion stands lie inside rings	6
The lion stands alone lie inside rings	7
The lion stands all alone lie inside rings	8

Non-garden-Path Sentences

Subject-verb type

The river twists around the valley	6
The river twists down around the valley	7
The river twists down below around the valley	8

Modifier-subject type

The wool jackets ripped in pieces	6
The wool jackets soon ripped in pieces	7
The wool jackets shortly after ripped in pieces	8

by inserting a one-word phrase in a third of them and a two-word phrase in a third. The phrases were inserted in the same way as in the sentences, except that all three groups of Ss saw the same length version of each non-sentence.

To increase the likelihood that the garden path would be mistakenly followed, the garden-path sentences were always preceded by a sentence of the opposite type (except when they were preceded by non-sentences). Thus to the degree Ss would expect the same kind of sentence they just read, they would be more likely to misinterpret the garden-path sentences initially. Other than meeting this constraint and the constraint of using equal numbers of each type of sentence, the order of the sentences and non-sentences was random. It was virtually impossible for an S to detect the above constraint on the order of the garden-path sentences.

Results and Discussion

In analyzing the results, means for each S were computed for correct response only and then these were averaged to produce the overall mean RTs. The analyses of variance were based on the averages for each S. In Experiment 1, the Ss did not respond in the given time period on 9% of the trials, and approximately 15% of their responses were errors.

The overall average RTs for all the conditions in Experiment 1 are shown in the left half of Fig. 1. As is quite evident from the graph, the inserted words took no longer to process in the garden-path sentences than in the non-garden-path sentences. An analysis of variance shows for the subject-verb-type sentences
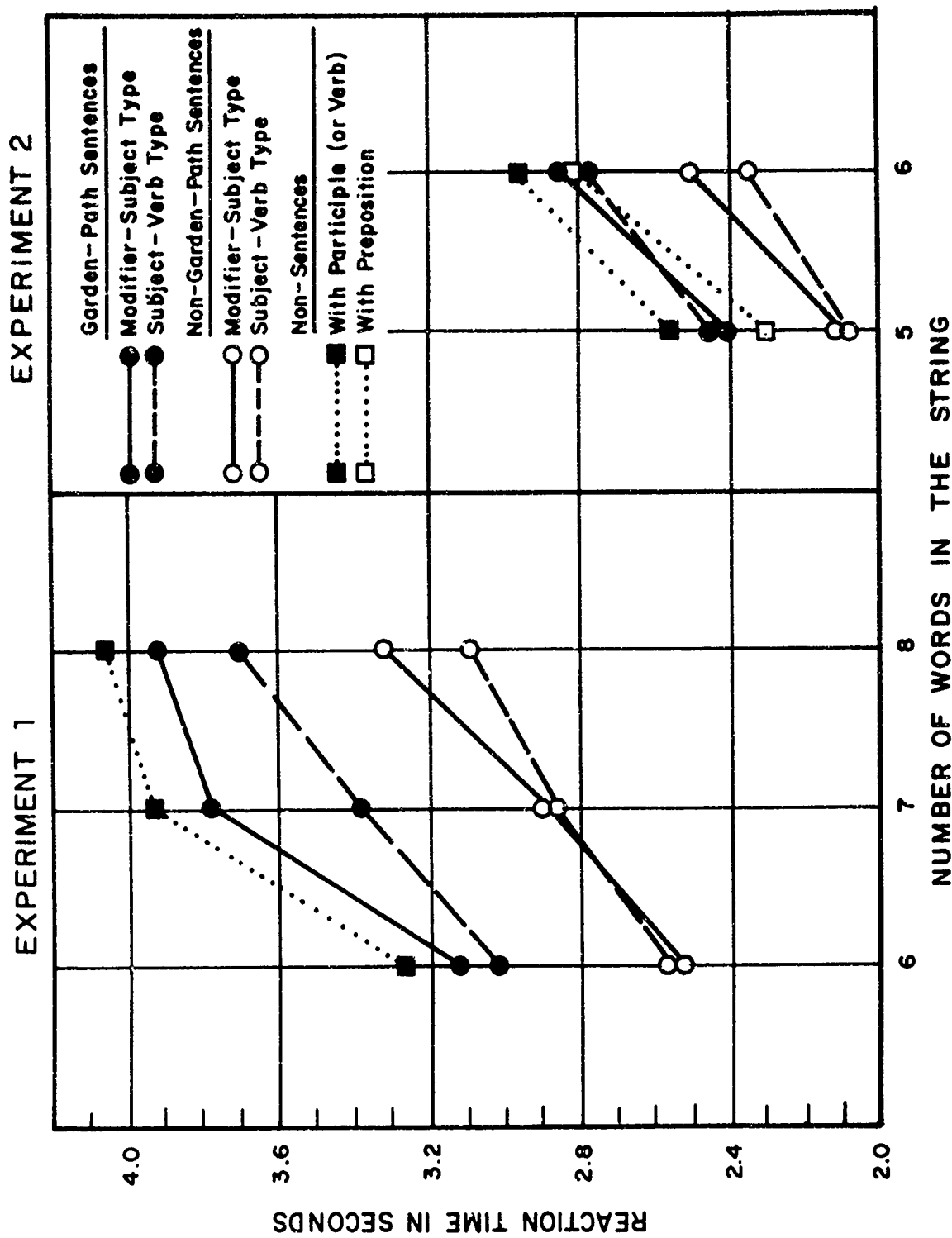
247

Fig. 1. Average reaction times in two experiments to garden-path and non-garden-path sentences as a function of the number of inserted words.

that the difference between garden-path and non-garden-path sentences is significant, $F(1,138) = 49.12$, $p < .01$, that the effect of the number of inserted words is significant, $F(2,138) = 22.21$, $p < .01$, but that the interaction is not significant, $F(2,138) = .37$. The corresponding figures for the modifier-subject sentences are $F(1,138) = 57.6$, $p < .01$, for the garden-path vs. non-garden-path differences; $F(2,138) = 25.8$, $p < .01$, for the effect of sentence length, and $F(2,138) = 1.19$, NS, for the interaction.

The failure to find any interaction suggests that for short sentences of this kind, at least, people can reinterpret a garden-path sentence without reprocessing it sequentially. Hence, the name garden path may be somewhat misleading, since these results suggest people do not reinterpret garden-path sentences by returning to the fork where they made a mistake and then going down the right path. Apparently, people can locate directly those words in the sentence that have been misassigned, revise their interpretation of those words, and at the same time retain successful interpretations for other words or phrases. That is to say, people appear to process sentences rather like a bottom-up parser. Presumably, they use some kind of semantic and/or syntactic segmentation in order to direct their reinterpretation to the key words that have been misinterpreted and away from the temporal or locative phrase that was correctly interpreted.

EXPERIMENT 2

Because of our failure to find any reprocessing of the inserted words in the first experiment, we wanted to see if there was any insertion that would require reprocessing. To this end,

we decided to insert an adjective before the two key words, such that the adjective modified one or the other depending on which way the key words were interpreted. For example, in "The old country houses many refugees," "old" modifies "house" in the most likely misinterpretation and "country" in the correct interpretation. Therefore, we thought that the inserted adjective might have to be reprocessed in garden-path sentences. This led to the prediction that the insertion of an adjective would lead to greater RT increases in garden-path sentences than in non-garden-path sentences.

Method

The method in this experiment was in most respects the same as in Experiment 1. We will describe here only the changes from the first experiment.

The Ss were 16 of the 24 Ss who were run in Experiment 1. Because the sentences were shorter and the task somewhat easier, the display duration for the word string was reduced from 5 sec to 4.5 sec. The S's response was recorded if it occurred any time between 0.5 sec and 4.5 sec after the onset of the word string. Very few RTs were lost in Experiment 2 because of this restriction.

There were 64 sentences and 24 non-sentences (in total 88 word strings) in each run. The Ss were told to expect about 30% of the strings to be non-sentences. As can be seen in Table 2, there were the same four types of sentences in this study as in the last study. There were only two different lengths, however, those with adjectives inserted and those without. Hence, there were only two different groups of Ss in this experiment; one group

Table 2

Illustrative Sets of Sentences and Non-Sentences in Experiment 2

Garden-Path Sentences	Words per String
Subject-verb type	
The country houses many refugees	5
The old country houses many refugees	6
Modifier-subject type	
The newspaper prints got smudged	5
The controversial newspaper prints got smudged	6
<u>Non-garden-Path Sentences</u>	
Subject-verb type	
The window opens from above	5
The locked window opens from above	6
Modifier-subject type	
The bank checks were perforated	5
The new bank checks were perforated	6
<u>Non-Sentences</u>	
With participial phrase	
The Chinese pagodas built then	5
The exquisite Chinese pagodas built then	6
With prepositional phrase	
The soap operas on television	5
The latest soap operas on television	6

saw one version of each sentence, and the second group saw the other version. In total, the two groups saw eight sentences of each type for each different sentence length. The sentences in this study had five or six words and, thus, were shorter than those in Experiment 1, which had from six to eight words. The sentences were an entirely new set from those in Experiment 1.

The adjectives inserted into the garden-path sentences were constructed so that which word was modified would change depending on how the key words ("country houses" or "newspaper prints" in Table 2) were interpreted. The adjectives inserted in the non-garden-path sentences and non-sentences were generally similar to the ones used in garden-path sentences.

The non-sentences were constructed somewhat differently in the second study, in part to make the task a bit easier, so that there would be less variability in RTs and fewer errors. There were two kinds of non-sentences—those with a participial phrase that looked like a verb phrase, and those with a prepositional phrase. Examples are shown in Table 2. The participial types were like the sentences with no verb in Experiment 1. The prepositional types were not used in Experiment 1 at all, and looked much more like non-sentences than any of the non-sentences in Experiment 1.

Results and Discussion

In Experiment 2, the Ss did not respond on about 2% of the trials, and approximately 9% of their responses were errors. As is evident from these statistics and the average RTs for the two experiments shown in Fig. 1, this task was much easier than the other.

252

The graph in the right half of Fig. 1 shows that the insertion of an adjective did not produce an interaction either. An analysis of variance for the subject-verb type sentences shows the garden-path vs. non-garden-path difference to be significant, $F(1,60)=8.16$, $p<.01$,, the effect of number of words to be significant, $F(1,60)=4.61$, $p<.05$, and the interaction to be non-significant, $F(1,60)=.035$. The corresponding analysis for the modifier-subject type sentences shows the garden-path vs. non-garden-path difference to be significant, $F(1,60)=4.35$, $p<.05$, the effect of number of words to be significant, $F(1,60)=7.73$, $p<.01$, and the interaction to be non-significant, $F(1,60)=.00029$.

The failure to find an interaction in the second experiment is disappointing, though in retrospect it does seem possible to tell whether the string is a sentence or not without reconsidering the adjective. We suspect that reprocessing time in garden-path sentences depends entirely on how easily the pair of key words can be reinterpreted. The only factors likely to affect reprocessing time, then, are those that determine the degree to which the reader will be locked in on a particular interpretation of the key words.

Considering both graphs in Fig. 1 together, the RT to non-sentences in Experiment 1 and to non-sentences with participial phrases in Experiment 2 are consistently from .1 to .2 secs slower than the slowest times for sentences. This suggests that Ss spent a limited amount of effort, as determined by some criterion, looking for a meaningful reinterpretation, and failing that gave up and responded "No." The fact that RTs for non-sentences with prepositional phrases in Experiment 2 came out faster than RTs for some sentence types indicates that these non-sentences could

be rejected without attempting to reinterpret them, because they lacked a verb or anything like one. Thus, the Ss in this experiment used both kinds of rejection strategies that we considered in an earlier paper (Collins and Quillian, 1970) for true/false RT tasks. It may be that rejection strategies in general will vary markedly depending on the task and even the particular sentence or word given on any trial.

CONCLUSION

It seems clear from these two experiments that people can reinterpret garden-path sentences without reprocessing any words except those originally misinterpreted. We think this implies that people can locate directly by semantic or syntactic segmentation just what words have been misassigned and, at the same time, retain successful interpretations for other words or phrases. This suggests as Lindsay (1964) has argued that sentence processors should attempt to interpret relations between words within segments which can be retained independently of how the segments themselves are interrelated. The interpretation of an entire sentence must be constructed out of the interpretations of its segments. Therefore, these results favor a bottom-up process as opposed to a top-down process in the analysis of sentences by computer.

REFERENCES

Collins, A. M. and Quillian, M. R. Experiments on semantic
   memory and language comprehension. To appear in
   Cognition in Learning and Memory, L. W. Gregg (ed.).
   New York: Wiley, 1970, in press.

Feldman, J. and Gries, D. Translator writing systems.
   Communications of the ACM, 1968, 11, 77-113.

Lindsay, R. K. A heuristic parsing procedure for a
   language learning program. Information processing
   report No. 12, The University of Texas.

Quillian, M. R. The Teachable Language Comprehender: A
   simulation program and theory of language. Communications
   of the ACM, 1969, 12, 459-476.

255

DOCUMENT CONTROL DATA - R & D

Security classification of title body of abstract and indexing annotation must be entered when the overall report is classified

1 ORIGINATING ACTIVITY *(Corporate author)*	2a. REPORT SECURITY CLASSIFICATION
Bolt Beranek and Newman Inc. 50 Moulton Street Cambridge, Massachusetts 02138	UNCLASSIFIED
	2b. GROUP

3 REPORT TITLE

INFORMATION PROCESSING MODELS AND COMPUTER AIDS
FOR HUMAN PERFORMANCE

4 DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Semiannual Report No. 7 covering period 1 January to 31 July 1970

5 AUTHOR(S) *(First name, middle initial, last name)*

John A. Swets, Daniel N. Kalikow, Dennis H. Klatt, Mario C. Grignetti,
Duncan C. Miller, Wallace Feurzeig, Allan M. Collins and M. Ross Quillian

6 REPORT DATE	7a. TOTAL NO OF PAGES	7b. NO. OF REFS
31 July 1970	255	

8a. CONTRACT OR GRANT NO	9a. ORIGINATOR'S REPORT NUMBER(S)
F44620-67-C-003	
b. PROJECT NO 9727	BBN Report No. 2008
c. ARPA Order No. 890, Amendment No. 4	9b OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d.	

10 DISTRIBUTION STATEMENT

Distribution of this report is unlimited.

11 SUPPLEMENTARY NOTES	12 SPONSORING MILITARY ACTIVITY
Sponsored by the Advanced Research Projects Agency, Dept of Defense, under AFOSR Contract	Air Force Office of Scientific Research, Arlington, Virginia 22209

13 ABSTRACT

Progress is reported on four research tasks. We have designed and are currently running an experiment to test the effectiveness of our computer-based phonology instructional system for second-language learning, using Spanish-speaking students with English as the target language. In our research on models of human-computer interactions, we have performed experiments demonstrating that the provision of certain incentives to the users of a time-sharing system can have the effect of shaping patterns of user-choice behavior which improve the overall efficiency of the system. The investigation of programming languages as a tool for cognitive research has led us to the development and construction of a wireless computer-controlled vehicle to aid students in conceptualizing previously abstract processes in problem solving. We have, in addition, conducted an experiment, in teaching the programming language LOGO to a group of hard-to-teach students, and have investigated the validity of standard measurements of achievement level. Our studies of human memory and language processing have further elucidated the cognitive operations involved in the storage, retrieval, and utilization of factual material.